Indiana Water Resources Research Center
Annual Technical Report
FY 2014

Introduction

Indiana Water Resources Research Center 2014 Program and Management Report

Overview: This report covers the activities of the Indiana Water Resources Research Center (IWRRC) for the period March 1, 2014 to February 28, 2015 and was written by Ronald F. Turco, Director of the center. The report is provided to meet requirements and obligations under the 104 (B) of the USGS water centers program. The objectives of the fiscal year 2014 program of the IWRRC have been: (1) to continue to engage the water community in the State of Indiana as related to water research and education; (2) to chair the dedicated water community at Purdue University–the Purdue Water Community (http://www.purdue.edu/dp/water/about.php) and build a water faculty at Purdue (http://catalog.e-digitaleditions.com/i/351089-protecting-indianas-water-future) ; (3) foster a research programs that encompass water issues related to: contaminants that is primarily focused on the Wabash River and in support of the projects aid in the development of grant submission for major efforts; (4) continue to support an outreach program related to water and water quality (in particular rural water protection/safety), (5) to strengthen interactions with State regulatory agencies, the Agriculture Industry, water industry and Federal Agencies, meetings with USGS, and Indiana Department of Natural Resources and (6) Organized and ran an Indiana water conference.

The IWRRC and Wabash River Enhancement Corporation (WRRC) have maintained a strong relationship over the past year. We are now in the fourth year of our 319 project entitled "Region of the Great Bend of the Wabash River Implementation project" where IWRRC is active with WREC in helping to evaluate projects for potential cost-share under the implementation effort and we engaged in number of new project startups. The IWRRC-WREC collaboration led to project entitled "Deer Creek-Sugar Creek Watershed Management Plan and Implementation Program" and work on the effort is ongoing. We also initiated a new project entitled the "Sugar Creek Water Sampling Project" working with the Clinton County Soil and water district to better understand regional impacts on water quality. Working with Colorado State University we developed and submitted to EPA a proposal entitled "Smart Water Hub: Community Modeling Platform for Sustainable Urban Water Management." This effort allowed an interesting opportunity to draw in a number of new water faculty for the collaborative effort.

The IWRRC has been active with the Purdue University water community (PWC) and have facilitated a number of campus wide meetings to engage this group. We have been primarily interested in developing grant applications.

International, we have continued to work with Purdue's office of global engineering on a number of water projects with efforts in China, India and Mexico. We have worked with the Purdue University Ecopartnership (http://www.purdue.edu/discoverypark/ecopartnership/) and are active in their efforts to host a major meeting in the fall of 2015. We submitted a number of effort with possible project in Colombia. Our goal has been the development of effective partnerships leading to real improvements in water quality.

For this reporting period, we continue the strategic outreach alliance with the Purdue Pesticide Program office for the development of document and educational materials on methods to prevent water contamination. By leveraging our funds with the Purdue Pesticide Program office's core efforts we are using the opportunity to include the IWRRC in many of their programs. Our efforts have established a constant and vital outreach effort that is associated with prevention rather than remediation of environmental problems. In the future we are increasing our support of the PPP office. Project 01: Program Administration and State Coordination

The administrative portion of the project has been used to support the management of the IWRRC's research projects and to facilitate the development of other research projects. We have also stepped up our efforts to coordinate campus level interactions (helping to create the Purdue Water Community) with state and federal agencies. All of these efforts have the ultimate goal of improving the quality of water resources in the State of Indiana. We have used a limited amount of money on the administrative portion but it has allowed the IWRRC director some means to invest time in the efforts to integrate with state and federal agencies. Most of IWRRC funds are used for projects and the director's time is contributed to the project. The IWRRC director has worked with state and federal environmental agencies, the governments of Indiana's cities and counties and key citizen groups on water education and water resources planning activities. In this way, the results from the research projects can be transferred to interested individuals in the state. The IWRRC director has participate in important national and international meetings related to water and environmental protection.

Projects Areas

1. Work with community projects has continued including working with the Wabash River Enhancement Corporation (WREC) on a Volunteer Water Quality Monitoring project to allow opportunities for volunteer monitors to assess water quality conditions throughout the watershed. WREC its partners conducted a fall and spring Wabash River Sampling Blitz in 2014. Connecting volunteers to the Wabash River: During each spring and fall event, approximately 175 volunteers mobilize to collect water samples from 258 stream sites within the Region of the Great Bend of the Wabash River and Wildcat Creek watersheds. The Wabash Sampling Blitz is dedicated to helping watershed residents learn more about the quality of the Wabash River. This portion of the Blitz provides information to the community through various media outlets, public information discussions, the WREC Wire (e-newsletter), the Wabash Sampling Blitz website and via partner newsletters and programs. During the previous 8 events (going back 4 years), volunteer groups sampled three to four stream sites collecting field measurements for temperature and transparency, using test strips to analyze pH and nitrate at a minimum, and filling sample bottles for laboratory analysis of E. coli, nitrate+nitrite, orthophosphorus, and total organic carbon. Sample results were mapped by subwatershed drainage and posted to www.wabashriver.net as soon as possible following the event. In total 600 unique volunteers participated in the sampling blitzes.

2. Organized and ran a major water conference "Defining Indiana's water needs" December 12. 2014, Hyatt Regency Indianapolis Indiana. a. Speaker and Topics: i. Shahzeen Attari, Indiana University, Perceptions of water use (copy of Shahzeen's PNAS paper is also attached) ii. Laura Bowling, Purdue University, Who gets it? Water use in Indiana now and tomorrow iii. Jack Wittman, INTERA, Bloomington, IN, Institutional Analysis of Water in Indiana iv. Jennifer Freeman, Purdue University, Are there health concerns associated with current allowable limits of contaminants in our drinking water? Fishing for answers. v. Andrew Whelton, Purdue University., Preparing Indiana for Drinking Water Disaster Response and Recovery: Lessons Learned from the Freedom Industries Chemical Spill vi. Ms. Jill Hoffman, EmpowerResults, Indianapolis, IN, a Facilitated breakout session - defining our needs. b. Attendees over 100 attended for the event from: i. University Faculty from (Purdue, IU, Ball State, IGS, IUPUI) ii. Industry Members from (Duke, KCI tech, Burke Eng., Citizens, Wessler Eng., Xenon, INTERA) iii. Environmental groups (TNC, WREC, HEC) iv. Regulatory/government (IDEM, IDNR, ISDA, NRCS, the Governor's office) c. A document describing outcomes is in development.

3. We have also continued working along with the Wabash River Enhancement Corporation, our partners, and education and outreach committees to provide numerous opportunities for watershed stakeholders to learn about the Wabash River and the Region of the Great Bend of the Wabash River watershed; facilitated education-based events; and coordinated programs to recognize the opportunities and commitments made by businesses and individuals throughout the watershed. Public meetings, the Clear-Blue-Green business certification program, field days, workshops, and the Wabash Sampling Blitz are just some of the activities used to educate our stakeholders.

4. In conjunction with the Tippecanoe County soil and water conservation district office, we working with cover crops to reduce N leaching and runoff as well as to improve soil health. This links to the use of infield anaerobic bioreactors as a means of reducing soluble N that can be discharged to surface water.

Grant Applications Submitted thorough/with IWRRC:

a. (Funded and ongoing) IDEM-319 $94,835 Clinton Cty Soil Water Dist Sugar Creek Water Sampling Project b. (Funded and ongoing) USDA-CIG $165,000 Using cover crops to improve soil health and moisture retention. c. (Funded and ongoing) IDEM-319 $240,000 Region of the Great Bend of the Wabash River Implementation Project with L. Prokopy, S. Peel and R. Goforth.

d. (Funded and ongoing) USDA-CAP: $2,875,642 Sustainable Production and Distribution of Bioenergy for the Central USA with J. Volenec, S. Brouder, others

e. (Funded and ongoing) IDEM-319 $132,000 Deer Creek-Sugar Creek Watershed Management Plan and Implementation Program. Project with S. Peel and R. Goforth.

f. (Closed) SUNGRANTS: Optimization of biomass productivity and environmental sustainability for cellulosic feedstocks: Land capability and life cycle analysis. $875,000 S.M. Brouder, PI, R.F. Turco, J.J. Volenec, D.R. Smith and G. Ejeta CoPIs

g. (Closed) USDA NRI, Managed Ecosystems. Ecological services of agro-biofuels: productivity, soil C storage, and air and water quality. $399,999. Submitted Dec. 2007. S.M. Brouder, PI, R.F. Turco, J.J. Volenec, D.R. Smith and G. Ejeta CoPIs. h. (Closed) ALCOA 95,000 Bauxite Residue in Soil. R. Turco.

i. (Closed) IDEM-319 Development and Demonstration of Outcomes-Based Evaluation Framework for the Indiana Nonpoint Source Program. Developed with Jane Frankenberger, and Linda Prokopy.

j. (Closed) IDEM 319: Wabash River: Lafayette-West Lafayette Reach of the Wabash River Watershed Management Plan. Submitted in conjunction with the Wabash River Enchantment Corporation $700,000. L. Prokopy, L. Bowling, K. Wilson and R. Turco. Bridging grant approved for one year of additional support.

k. (Closed) USDA Conservation Effects Assessment Program. $660,000. Watershed-Scale Evaluation of BMP Effectiveness and Acceptability: Eagle Creek Watershed, Indiana. Developed with Jane Frankenberg, Lenore Tedesco, Jerry Shively, Linda Prokopy. This was an outgrowth of an effort submitted last year to EPA but note funded: Creating sustainable drinking water supplies for Central Indiana: Innovations to achieve reductions in watershed and reservoir nutrient levels

Associate Director: Dr. Linda Prokopy, Professor Forestry and Natural Recourses

External Board of Advisors Membership: Dr. Jack Wittman, Ph.D., Bloomington IN Dr. Bill Guertal Director, USGS Indiana Water Science Center, Indianapolis IN Mr. Jeff Martin, USGS Indiana Water Science Center, Indianapolis IN

Faculty Advisory Committee: Dr. Linda Lee, Professor and Director of ESE Dr. Indrajeet Chaubey, Agriculture and Biological Engineering Dr. Larry Nies, Civil and Environmental Engineering

Research Program Introduction

None.

Attached-Growth Lagoons for Wastewater Nitrification in Small Communities

Basic Information

Title:	Attached-Growth Lagoons for Wastewater Nitrification in Small Communities
Project Number:	2013IN356B
Start Date:	3/1/2013
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	IN-004
Research Category:	Water Quality
Focus Category:	Nutrients, Treatment, Water Quality
Descriptors:	
Principal Investigators:	Ernest R. Blatchley, Ronald F. Turco

Publications

There are no publications.

ATTACHED-GROWTH SYSTEM FOR NITRIFICATION AT LOW TEMPERATURE

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Abstract: Lagoon systems are commonly used in small communities for domestic wastewater treatment. These systems are simple and economical to operate, and are often appropriate for use in areas where land costs are low. Lagoons are effective for removal of conventional pollutants under warm-weather conditions; however, biochemical nitrification is hindered in suspended-growth lagoons during periods of extended cold weather. Attached-growth nitrification systems, as compared to suspended-growth systems, have been reported to yield improved biochemical nitrification under cold-weather conditions. In this work we investigated a commercially-available biochemical nitrification reactor (i.e., BOBBER) that includes surfaces to promote development of attached-growth nitrifying communities. The BOBBER system has been applied to an aerobic lagoon system at Wingate, IN. Results of monitoring of this system have indicated improvements in oxidation of ammonia-N, especially during winter months.

To examine the behavior of this system in a more controlled setting, two laboratory-scale mini-BOBBER systems were installed in a temperature-controlled room. The systems were treated with an ammonium chloride feed solution, and allowed to approach steady-state conditions at nominally 20°C, 15°C, 10°C, and 5°C. Concentrations of nitrate and nitrite, as well as pH and other process variables were measured daily during these experiments. These results were analyzed to quantify ammonia-N removal rates. Similar calculations were applied to the data from the full-scale lagoon system at Wingate.

Ammonia-N removal in the laboratory-scale lagoon system always exceeded 95%, even when at temperatures of 4.6°C. However, the full-scale lagoon system was not as effective, with ammonia-N removal of approximately 74% at the same temperature. Possible explanations for these differences in behavior include: competition from heterotrophs, relatively low influent ammonia-loading into Wingate second lagoon, and a relatively small population of nitrifying bacteria at Wingate.

These findings suggest that it is possible to maintain effective biochemical nitrification in attached-growth systems even under cold-weather conditions. Satisfactory performance of these systems will depend on hydraulic design and N loading rates of the systems.

Problem and Research Objectives: Attached-growth systems appear to be less sensitive to cold weather conditions than suspended-growth systems. Field implementation of a commercial system (BOBBER) designed to promote development of an attached-growth nitrifying community at Wingate, IN has shown promise, in that nitrification was improved at during winter conditions. As such, these systems may represent a viable alternative for ammonia-N control in small wastewater treatment facilities. Therefore, to improve our understanding of attached-growth nitrification in lagoon systems, a laboratory-scale (mini-BOBBER) lagoon system was installed in the Environmental Engineering Laboratories at Purdue University.

The objectives of this study were to:

i. Compare nitrification dynamics at low temperature in a real lagoon system using full-scale BOBBER reactors with a laboratory-scale lagoon system using mini-BOBBER reactors.
ii. Quantify nitrification dynamics under controlled conditions, involving pure ammonia-N feed without organic carbon substrates.
iii. Investigate the relationships between ammonia-N removal rate and ammonia-N concentration in attached-growth systems at different temperatures.

Methodology: A series of mini-BOBBER experiments was conducted. The mini-BOBBER systems were designed and operated to simulate the nitrification process at the Wingate lagoon system. Both types of media used in these experiments were suspended at Wingate second lagoon for 2 weeks to establish the nitrifier attached communities.

To mimic attached-growth nitrification at Wingate, two mini-BOBBER systems provided by Bradley Environmental were installed in a temperature controlled room. The reactors were operated under the identical conditions, in terms of reactor volume, temperature, influent composition, influent flow rate and discharge rate, aeration rate, etc. BOBBER system 1 was operated with Kaldnes K1 media with a specific surface area of 300 m^2/m^3 while the BOBBER system 2 was operated with RK media with a specific attach area of 750 m^2/m^3. The two BOBBER reactors were operated for 101 days with 4 temperature stages (nominally 20°C, 15°C, 10°C, and 5°C). For each temperature stage, the performance of the system was allowed to approach a steady-state condition. Figure 1 is a schematic illustration of the setup of the mini BOBBER experiments.

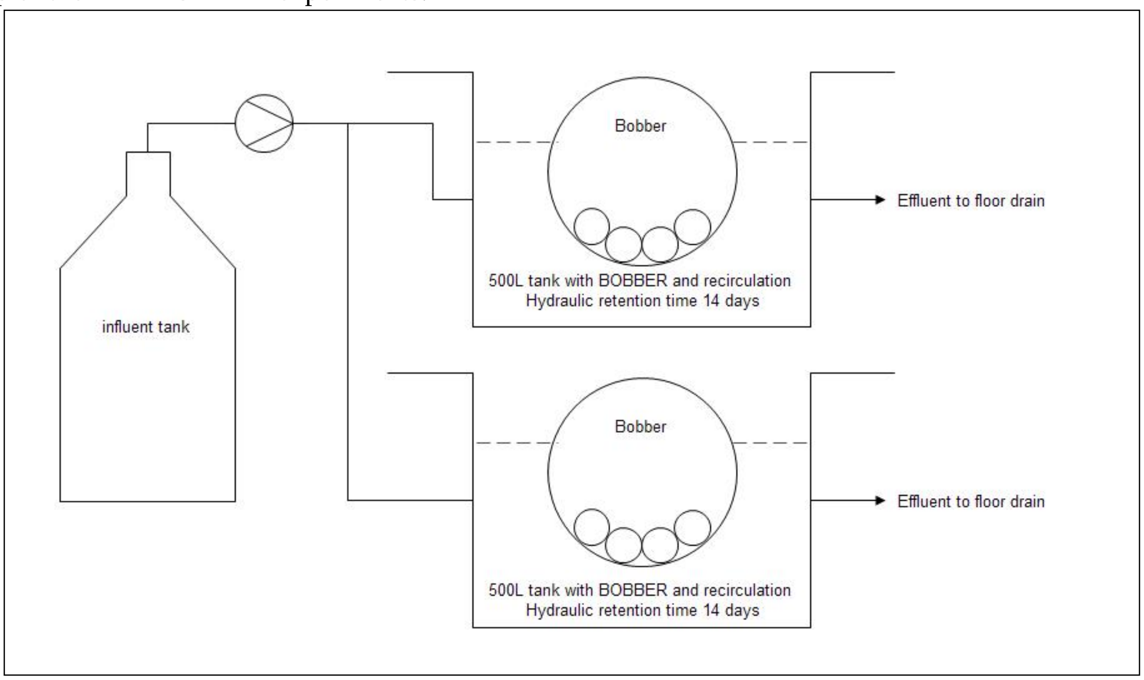

Figure 1. Schematic of mini BOBBER experiments.

Synthetic wastewater (SWW) from the influent tank was pumped into two tanks that included mini-BOBBER reactors (See Figure 2 (a)) at a fixed flow rate (24.5 mL/min). This flow rate was chosen to provide a hydraulic retention time of 14 days, which is representative of the operation of the Wingate lagoon system. In order to keep influent and discharge flow rate the same, the treated water was designed to overflow through a PVC pipe (See Figure 2a) to a floor drain.

The mini-BOBBER reactor is pictured in Figure 2b. There were two air supplies: air supply #1 provided aeration and drew water into the circulating part from the inlet at the bottom; air supply #2 promoted circulation of water and media in the mini-BOBBER reactor. Both air supplies promoted O_2 transfer, which was needed to satisfy O_2 that was expressed by biochemical oxidation of influent ammonia-N. Water was designed to spray out from outlet on the top of mini-BOBBER reactor.

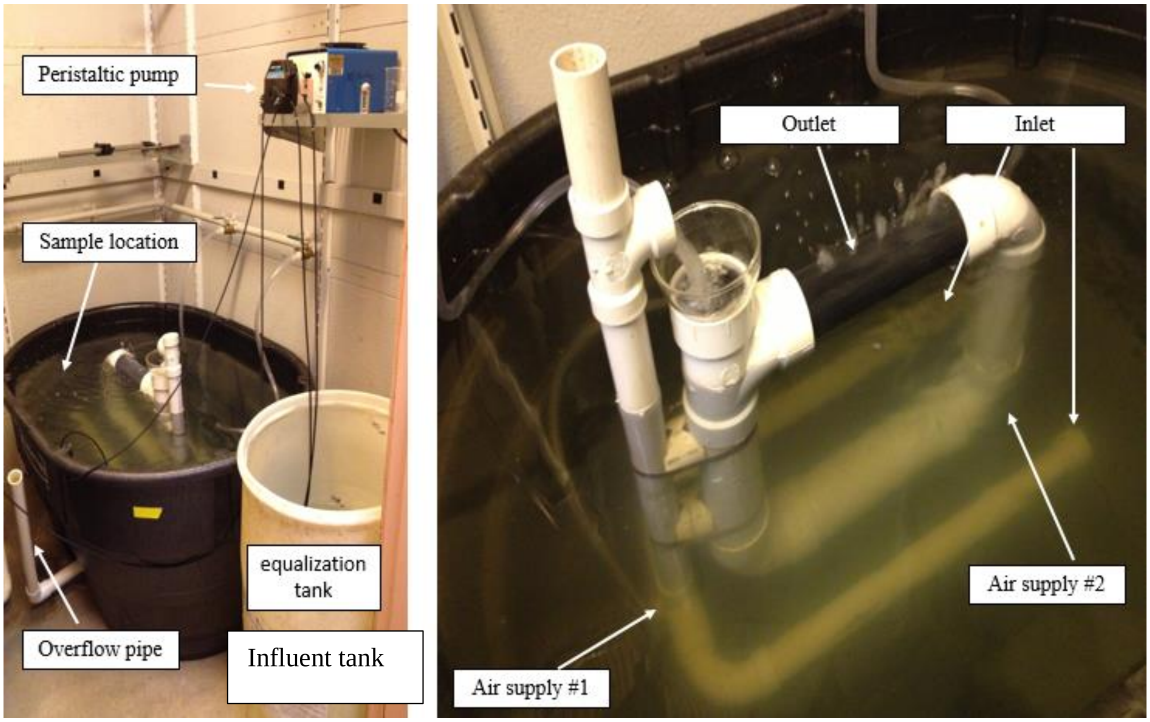

Figure 2. Images of mini-BOBBER experiment design (a) Left, image of lab-scale lagoon system; (b) Right, image of mini-BOBBER reactor.

Experiments with the mini-BOBBER systems were conducted as follows:

1. Each tank was filled with 500 L synthetic wastewater (SWW, composition defined below) and placed in a temperature-controlled room at an initial temperature of 20°C.
2. Both types of media were inoculated with a mixed culture of bacteria from the Wingate secondary lagoon, and subsequently the inoculated media (3.78 L of media per tank) were placed in the two mini-BOBBER reactors.
3. The influent tank was filled with SWW (Roughly 70 L per day) for a whole day before service, and the peristaltic pump was set at the flow rate of 24.5 mL/min. Water samples in influent tank and both mini-BOBBER tanks were taken periodically to measure pH, temperature, DO, ammonia-N, nitrite-N, and nitrate-N.
4. When the system had been operated under steady-state at 20°C for 2 weeks, the temperature was decreased to 15°C. Then, following similar steps, the system temperature was decreased to 10°C and 5°C, sequentially.
5. The system was operated at 5°C for 46 days.

SWW was used for all experiments in this study. SWW containing roughly 40 mg/L ammonia-N was prepared by dissolving ammonia chloride in dechlorinated tap water. This ammonia-N loading was determined based on the average influent ammonia-N concentration at Wingate lagoon. No organic carbon was included in the SWW. The composition of Purdue tap water, as reported by the Purdue water utility for some metals and other inorganic constituents, is included in Table 1.

Table 1. Composition of Purdue Tap Water with respect to common inorganic constituents.

pH	Alkalinity (mg/L as $CaCO_3$)	Calcium hardness (mg/L as $CaCO_3$)	Magnesium hardness (mg/L as $CaCO_3$)	Fe (mg/L)	Mn (mg/L)	Cu (mg/L)
7	320	300	120	0.49	0.154	0.57

According to the Consumer Confidence Report provided by Purdue University, West Lafayette Campus Water Works, most nutrients required for nitrifiers growth are included in Purdue tap water. Furthermore, tap water was dechlorinated by sodium bisulfite prior to use to minimize the influence of chlorine on microorganisms. During dechlorination, sodium bisulfite was added at a concentration of 10 mg/L to tap water to create a stock solution. Sodium bisulfite was added in slight stoichiometric excess of residual chlorine concentration to ensure complete dechlorination. Free chlorine and total chlorine were measured by the DPD/KI Colorimetric Method, as defined by *Standard Methods for Examination of Water and Wastewater*.

Samples were collected for measurements of pH, DO, temperature, ammonia-N, nitrite-N, and nitrate-N. pH was measured by an Accumet model 50 pH/ion/conductivity meter (Fisher Scientific) connected to a ROSS Ultra combination pH electrode (ORION). DO and temperature were measured by a YSI 550A DO meter. Ammonia-N was measured by an Accumet model 50 pH/ion/conductivity meter (Fisher Scientific) connected to a 95-12 ammonia electrode (ORIONNitrite-N and nitrate-N were measured by an Ion Chromatography (DIONEX) using an IonPac AS19 4*25 mm Analytical column (RFIC).

Principle Findings: The mini-BOBBER experiments were conducted over a period of 101 days, during which time the performance of each system was monitored using daily measurements of influent and effluent quality. Operating parameters including pH, DO, and temperature were measured daily, and remained stable during the entire experiment. Only the results for ammonia-N removal and the fates of nitrogen are reported here. Additional details of the results of these experiments will be presented in a manuscript that is to be submitted for publication.

Figure 3 illustrates time-course measurements of ammonia-N concentration for the mini-BOBBER experiments. Ammonia-N concentration showed a rapid decline during the first 10 days of the experiment. Then ammonia-N concentration reached steady-state roughly at first temperature stage. Comparatively small changes of ammonia-N concentration were observed during the three subsequent temperature stages (See Figure 3).

The rapid ammonia-N concentration decrease during the first 10 days of the experiment was probably due to a rapid increase of the concentration of nitrifiers, which was promoted by a high initial ammonia-N concentration (roughly 45 mg/L as ammonia-N). This period was also characterized by a rapid decrease of DO; at the end of this period, and for the remainder of the experiment, DO concentrations were maintained at or near equilibrium values for the temperatures of the experiment (data not shown). Because the system appeared to be undergoing acclimation in the first 10 days of the experiment, average ammonia-N concentration in the effluent was calculated without data from the first 10 days.

The average ammonia-N concentrations in both mini-BOBBER tanks during the four stages of the experiment are listed in Table 2. As temperature decreased, the average ammonia-N concentration increased slightly. However, effluent ammonia-N concentration was consistently well below the permit limitation values that are imposed on most municipal WWTPs, which are typically in the range of 3-6 mg/L (as N).

Table 2. Average ammonia-N concentration in both mini BOBBER tanks.

	Ammonia-N (mg/L)	
Temperature (°C)	Kaldnes K1 media	RK media
19.7	0.76	0.81
14.3	0.80	0.77
9.6	0.91	0.98
4.6	1.50	1.43

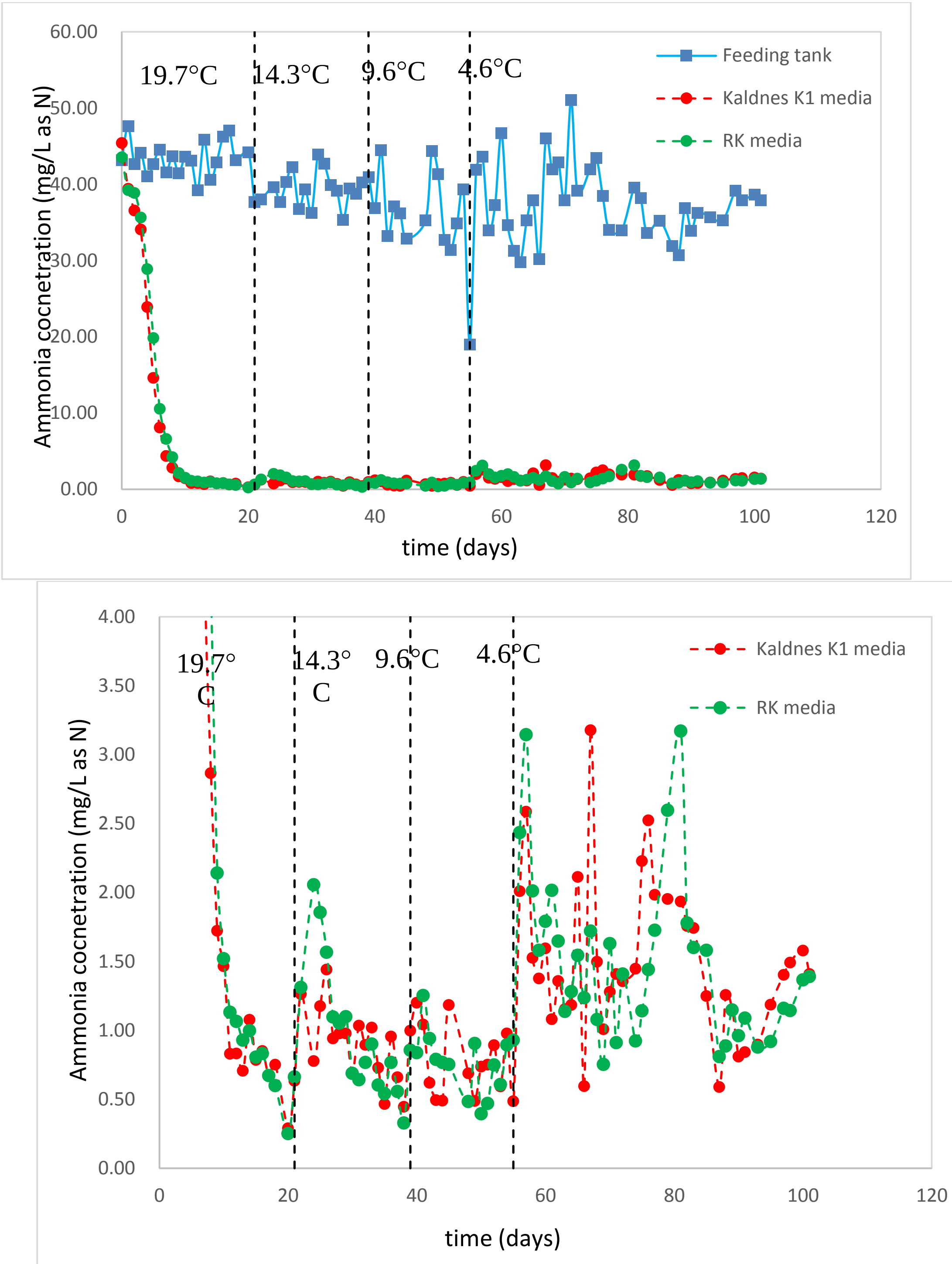

Figure 3. Time-course measurements of Ammonia-N from mini-BOBBER experiments. Also included are daily ammonia-N concentrations of both mini-BOBBER systems corresponding to average water temperature in each stage of the experiment. Upper panel gives the general ammonia-N concentration in both feeding tank and reactor, while the lower panel gives a more detailed ammonia-N concentration in the reactor with small vertical scale.

Time-course measurements of Nitrite-N and nitrate-N for the mini BOBBER experiments are illustrated in Figure 4. The nitrite-N and nitrate-N concentrations in the reactor with Kaldnes K1 media achieved equilibrium faster than the reactor with RK media. The possible reason for this is the different media type used. Since Kaldnes K1 media is smaller in size, the mixing for Kaldnes K1 media could be more efficient, which could lead to faster consumption of ammonia-N.

However, after the initial ammonia-N loadings in both reactors were depleted, nitrite-N and nitrate-N in both reactors achieved similar steady-state concentration. Additionally, nearly all nitrite-N in both reactors was converted to nitrate-N. Ammonia-N appeared to be a growth-limiting factor and the surface area for both types of media were not fully utilized. Therefore, in spite of the difference in specific surface area for both types of media, the steady-state nitrite-N and nitrate-N concentrations in both reactors were similar.

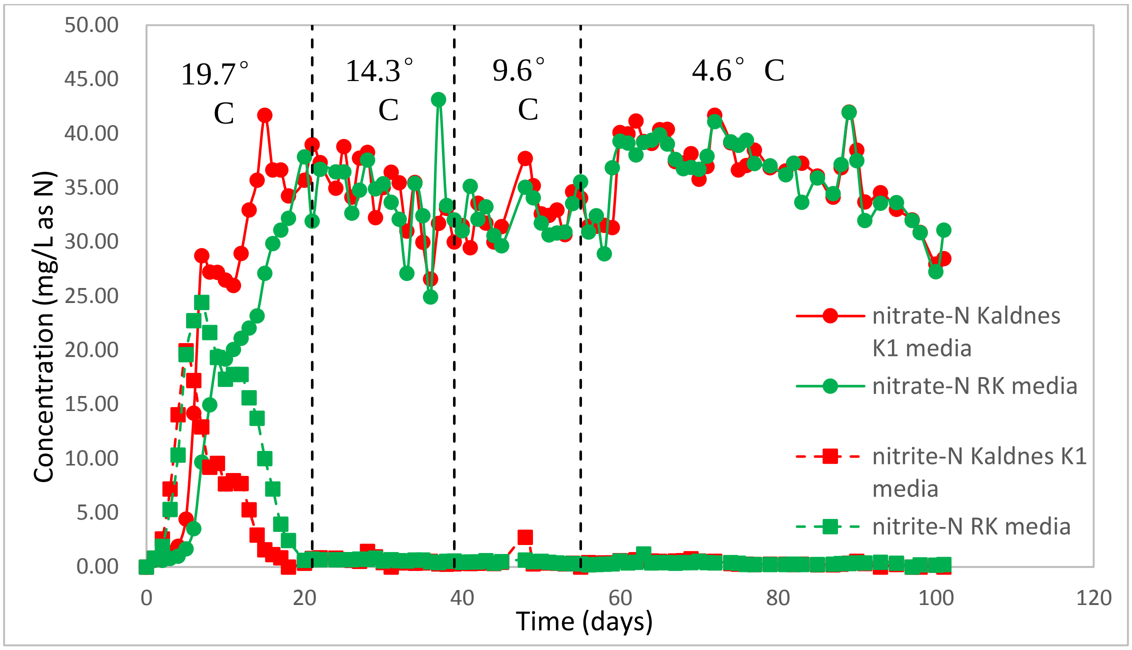

Figure 4. Nitrite-N and nitrate-N data of mini BOBBER experiments. Also included are daily nitrite-N and nitrate-N concentrations of both mini BOBBER systems corresponding to average water temperature in each stage of the experiment.

Nitrogen balances were conducted for both mini-BOBBER reactors based on the assumptions that all nitrogen in the system existed as ammonia-N, nitrite-N, and nitrate-N. Therefore, the nitrogen balance calculations were conducted under the assumption that no molecular nitrogen (N_2) or other forms of nitrogen (*e.g.*, N_2O) were present in the system. No measurements of N_2 or N_2O were included in this research. Therefore, formation of N_2 or N_2O in the liquid phase and escape of these compounds from the liquid phase to the gas phase were not accounted for in this model. Based on these assumptions, a nitrogen balance was developed, as shown in Eq. (1):

$$C_{total,N}=C_{ammonia,N}+C_{nitirite,N}+C_{nitrate,N} \quad (1)$$

Figure 5 illustrates the time-course behavior of $C_{total,N}$ from these nitrogen balance calculations for both reactors. The total nitrogen for both systems was dominated by nitrate-N for the majority of the period of these experiments, exclusive of the induction period (first 10-15 days), even after the temperature was reduced to 4.6°C. This indicates that the mini-BOBBER reactors with both types of media were able to convert most ammonia-N to nitrate-N at this ammonia-N loading, even under low temperature conditions.

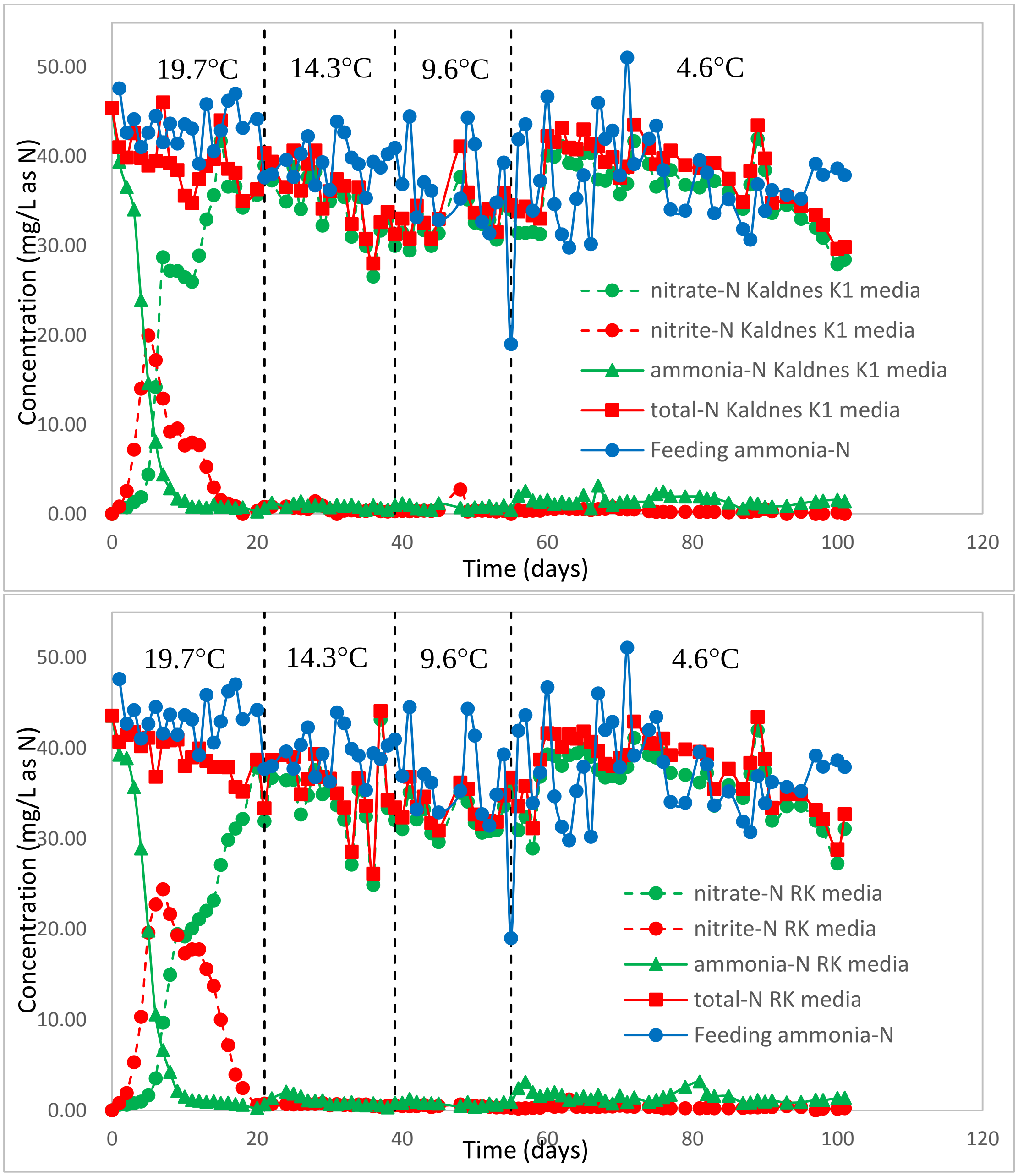

Figure 5. Nitrogen balance: (a) upper panel, nitrogen balance of the system using Kaldnes K1 media; (b) lower panel, nitrogen balance of the system using RK media.

Calculations of ammonia removal rate were conducted by application of the principles of mass balance. The reactor systems were each assumed to be well-mixed and only the media surfaces were counted in the calculation (*i.e.*, the walls of the tanks were not included in these calculations).

Figure 6 illustrates the specific ammonia-N removal rate as a function of time for both reactor systems over the course of this experiment. Table 3 provides a summary of the mean and standard deviation of the specific ammonia-N removal rate for both systems in all four phases of the experiment. Collectively, these summaries indicate that the two systems achieved similar ammonia-N removal rates after the initial period of acclimation. Temperature did not appear to alter the rate of ammonia-N removal substantially under this operating condition.

Table 3. Average specific ammonia-N removal rate at different temperatures.

	Specific ammonia-N removal rate (g/day/m^2)	
Temperature	Kaldnes K1 media	RK media
19.7 C	1.41+0.23	0.59+0.13
14.3 C	1.14+0.17	0.46+0.07
9.6 C	1.07+0.20	0.43+0.06
4.6 C	1.07+0.32	0.42+0.12
Media surface area (m^2)	1.14	2.85

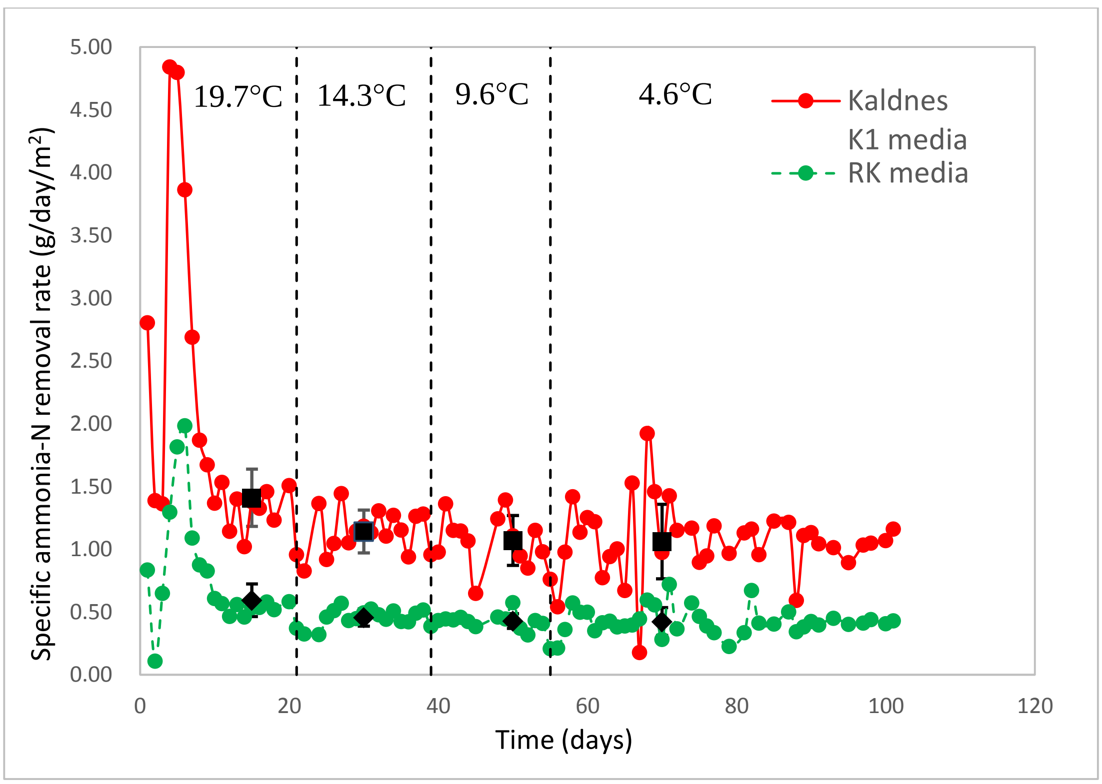

Figure 6. Specific ammonia-N removal rate of mini BOBBER experiments. Also included the average specific ammonia-N removal rate during each temperature stage.

In the mini-BOBBER experiments, efficient ammonia-N removal was achieved at temperatures from 4.6°C to 19.6°C. The observed ammonia-N removal was over 95%, even at 4.6°C. However, ammonia-N removal at the Wingate second lagoon where the BOBBERs were installed was less efficient (approximately 71%). The average specific ammonia-N removal rate (at temperature 5°C) at the second lagoon of the Wingate system was 0.66 g/day·m^2. For comparison, the average specific ammonia-N removal rate (at temperature 5°C) observed from the mini-BOBBER experiments was 1.07 g/day·m^2.

Possible reasons for the discrepancy between observations from mini BOBBER experiments and Wingate second lagoon include the following:

- The mini-BOBBER system was provided with an influent that contained ammonia-N as the only source of reduced-N, with no organic carbon. The presence of organic carbon will promote development of a heterotrophic community, which will compete with the nitrifying community. The presence of organic carbon and heterotrophs in real lagoon systems could hinder nitrification.
- The influent ammonia-N concentration into the second lagoon at Wingate was roughly 20 mg/L as N in cold-weather periods (During warm periods, the influent ammonia-N concentration into the second lagoon was round 2 mg/L as N). However, the feed solution concentration used in the mini-BOBBER experiments was roughly 40 mg/L as ammonia-N. A lower ammonia-N loading could contribute to the lower ammonia-N removal rate at Wingate. For example, if the ammonia loading is lower than the nitrification rate, the nitrifiers will consume most of the ammonia-N, and the effluent ammonia-N will be low.
- Nitrifiers in the mini-BOBBER experiments were fed a relatively stable ammonia-N loading. However, the ammonia-N loading at Wingate second lagoon was less stable. During warm periods, almost all ammonia-N was oxidized in lagoon 1 and the influent ammonia-N concentration into the second lagoon was typically 2 mg/L or less (ammonia-N loading for the mini-BOBBER experiments was roughly 40 mg/L). So the accumulation of nitrifiers at Wingate was presumably slower and the nitrifying bacteria population stayed at relatively low level, as compared to the mini-BOBBER system. When temperature decreased, the ammonia-N loading in the Wingate second lagoon increased, possibly because there were not enough nitrifiers to deal with the large ammonia-N loading. As a result, the ammonia-N removal rate decreased.
- The average bulk ammonia-N concentration in Wingate second lagoon (at temperature 5°C level) was 11.1 mg/L, while the average bulk ammonia-N concentration in mini BOBBER system (at temperature 5°C level) was approximately 1.5 mg/L. According to the relatively low ammonia-N removal rate with a higher bulk ammonia-N concentration observed at Wingate second lagoon, the main cause of this should be lack of nitrifying bacteria.

Significance: Attached-growth nitrification with mini-BOBBER reactors was demonstrated to achieve efficient ammonia-N removal (>95%) over a wide range of temperatures (4.6°C to 19.7°C). According to monitoring data from the Wingate lagoon system, the ammonia-N removal rate was increased greatly after the installation of the BOBBER reactors. However, the improvement still needs to be validated under conditions of extended cold temperature.

Attached-growth nitrification was observed to be less temperature sensitive than suspended-growth nitrification, which supports the application of attached-growth nitrification during cold periods. Additionally, the maximum ammonia-N removal rate under 4.7°C and 22.6°C were measured with SSW. However, these results were observed with simple ammonia-N loading, the performance with real wastewater still needs to be tested.

Attached-growth nitrification (such as BOBBER reactors) has great potential to deal with ammonia-N under low temperature range. This could be applied in many small communities with winter nitrification problems at relatively low cost (compared to mechanical wastewater treatment plant). Additionally, pre-attached BOBBER reactors could be added to new constructed wastewater treatment systems, the pre-attached BOBBER reactors are easy to transport and install, and they are able to perform nitrification immediately after installation.

Publications: A manuscript is being prepared for possible publication in the refereed literature. Another manuscript has been submitted for consideration as a podium presentation at a regional conference.

Grant Submissions: No additional proposals have been submitted. However, we are working with Bradley Environmental to examine possible sources of additional funding to extend this work.

Students: Funds from this grant were used to support Mr. Zhe Sun, who used this work as the basis of his M.S. research. Mr. Sun successfully defended his thesis in Spring 2014.

Abundance, Transport, and Retention of Pharmaceuticals and Personal Care Products (PPCPs) in Central Indiana Streams

Basic Information

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Publications

1. Jarvis, AL. The effects of the psychiatric drug carbamazepine on freshwater invertebrate communities and ecosystem dynamics. MS Thesis. Ball State University, May 2014.
2. Jarvis, AL. The effects of the psychiatric drug carbamazepine on freshwater invertebrate communities and ecosystem dynamics. MS Thesis. Ball State University, May 2014.

Abundance, transport and retention of pharmaceuticals and personal care products (PPCPs) in central Indiana streams

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Abstract / Summary

Persistence of pharmaceuticals and personal care products (PPCPs) in the environment is an emerging concern due to potential adverse effects on aquatic ecosystems and transport to human drinking water sources. We quantified both human and veterinary PPCPs throughout freshwaters of central Indiana underscoring the ubiquity of these contaminants. Research combined descriptive sampling of PPCP abundance with innovative enrichment studies to directly quantify PPCP transport and retention in freshwater. Additionally, we conducted *in vitro* and *in situ* experimental assessments of PPCP influence on aquatic organisms. Research was guided by two objectives: 1) Develop predictive models of PPCP abundance in lotic ecosystems; and, 2) Quantify variation in PPCP retention and transport via descriptive sampling and experimental techniques. We sampled 19 3rd order streams in central Indiana during baseflow conditions. Dissolved pharmaceutical concentrations were measured at each site in addition to stream physiochemical characteristics and organic matter biomass. Caffeine (24-135 ng/L), carbamazepine (1-88 ng/L), cotinine (4-34 ng/L), naproxen (5-15 ng/L), and paraxanthine (49-62 ng/L) concentrations varied among sites. Pearson correlations indicated only stream temperature, width, and autotrophic abundance were correlated with pharmaceutical concentrations. Structural equation modeling identified causal relationships between stream variables and pharmaceutical concentrations. Significant pathways included filamentous algal biomass and sediment percent organic matter effects on carbamazepine as well as nutrient and discharge effects. Additionally, significant effects of macrophyte biomass on caffeine were identified. These data and analyses highlight multiple interacting controls on pharmaceutical abundance in freshwater ecosystems. Experimental assessments identified sub-lethal effects of carbamazepine on both macroinvertebrates and yellow perch. Ephemeroptera had longer molt cycles when exposed to environmentally-relevant concentrations of carbamazepine in addition to a higher prevalence of abnormal behaviors. Yellow perch had lower growth rates when exposed to environmentally-relevant concentrations of carbamazepine in addition to reduced response to stimulus. At the ecosystem scale, carbamazepine was found to alter species diversity, organic matter composition, and nutrient concentrations through effects on specific organisms.

Problem and Research Objectives:

This study was conducted in the Upper White River (UWR) watershed, a tributary to the Wabash River and one of the most degraded watersheds in the country (USEPA 2002). The UWR watershed in central, Indiana encompasses 2,718 mi^2 across 16 counties and provided an excellent system to study PPCPs due to varied land use and PPCP sources. Since the Clean Water Act was passed by Congress in 1972, environmental managers and policy makers have made substantial headway in identifying and reducing point source discharge in the nation's waterways. Yet, >40% of these water bodies remain impaired, often because of nonpoint source pollution which often degrades freshwater integrity to a greater extent than point pollution. PPCPs can enter freshwaters via multiple sources including disposal of surplus drugs, human excretion into sewage, and runoff associated with therapeutic treatment of livestock. These sources can be routed to freshwater via urban sewage transport, ineffective or leaking septic tanks and landfills, or overland runoff. There have been numerous studies quantifying measurable concentrations of PPCPs and their metabolites in surface and groundwaters. Higher concentrations of PPCPs in water are generally associated with wastewater treatment effluent, but concentrations vary with secondary waste treatment procedures. Further, although effluent serves as a source of PPCP pollutants, streams across the US not influenced by wastewater can also have measureable concentrations of waste contaminants from residential, industrial, and agricultural sources. Once PPCPs enter into freshwater, they may be transformed, retained, or exported downstream. PPCP compounds can be transformed via biodegradation or photodegradation; retained via assimilation or sediment sorption, or if the compound is mobile and recalcitrant, exported downstream unaltered. All of these pathways may influence transport downstream to drinking water sources. Previous studies have consistently demonstrated the prevalence of PPCP compounds. However, current knowledge does not include an understanding of the spatiotemporal patterns of PPCP abundance in freshwater. Further, environmental transport and fate of these compounds have not been quantified to assess regulatory need. Because PPCPs are designed to have a physiological effect, it is likely they may influence organisms even at trace concentrations.

The overall objective of the study was to quantify spatial and temporal variability of abundance, transport, and retention of PPCPs in streams of the Upper White River (UWR) watershed of central Indiana. Research combined descriptive sampling with experimental assessments to directly quantify PPCP transport and retention in lotic ecosystems. Research was guided by two primary objectives:

1. Develop predictive models of PPCP abundance in lotic ecosystems.
2. Quantify variation in PPCP transport and retention using short-term enrichment experiments.

In addition, *in vitro* and *in situ* experiments were conducted to quantify the effect of PPCPs on aquatic organism populations, communities, and ecosystems.

Methodology:

*Descriptive Measurements: S*tream sites in the UWR watershed were selected for sampling and represented a range of urban and agricultural activity. At each site and sampling event, sediment and dissolved PPCP concentrations were measured in addition to multiple physiochemical parameters and characterization of the sub-watershed. Water and sediment samples were analyzed using high performance liquid chromatography with tandem quadruple mass spectrometric detection in collaboration with the Indiana State Department of Health (ISDH) chemical laboratories (Indianapolis). Analytes measured in each sample included 1,7-dimethylxanthine, acetaminophen, caffeine, carbamazepine, cotinine, DEET, gemfibrozil, ibuprofen, lincomycin, naproxen, sulfadimethoxine, sulfamerazine, sulfamethazine, sulfamethoxazole, sulfathiazole, triclocarban, triclosan, trimethoprim, and tylosin. Field blank samples and matrix samples were also collected at each site and sampling event to ensure data quality.

Additional filtered water samples (250 mL) were collected at each sampling event and site for chemical analysis at Ball State University including anions (NO_3, Br, Cl, PO_4, SO_4) and cations (NH_4, Li, K, Mg) using a Dionex 3000 Ion Chromatograph and dissolved organic carbon concentrations using a Schimadzu TOC-VC carbon analyzer. These chemical analyses aided identification of PPCP sources (e.g., manure, tile drainage, wastewater). Additional sediment samples (100 cm^3) were also collected and analyzed for organic matter and elemental content to inform potential for PPCP sorption as well as serve as an indicator of microbial activity and potential biodegradation of PPCPs. Physical parameters were also measured at each sampling event including flow, depth, width, oxygen, pH, temperature, specific conductivity and light to enable assessments of abiotic factors influencing PPCP abundance (e.g. photodegradation, dilution).

PPCP Enrichment Experiments: We enriched a an experimental stream reach on a Ball State University Field Station (Cooper-Skinner Farm) with select PPCP compounds (acetaminophen, carbamazepine, DEET, triclosan) to quantify transport and retention. Enrichment protocols followed standard nutrient enrichment protocols and consisted of dripping (~0.14 L/min) a concentrated solution of the target compound (contained in a 20 L carboy) and potassium bromide (conservative tracer) into the stream using a peristaltic pump until equilibrium was achieved (~2 hrs depending on discharge). Enrichments increased PPCP concentration to a maximum environmentally-relevant concentration within the reach (150 ng/L acetaminophen; 10 ng/L carbamazepine; 400 ng/L DEET; 10 ng/L triclosan). These enrichment concentrations were two orders of magnitude lower than lethal concentrations to any organism and high enough that fine resolution in concentration changes could be detected. Once equilibrium was achieved, downstream sites were sampled over ~30 min, moving from downstream to upstream, to quantify loss of the target compound over the reach followed by termination of the addition. Water and sediment chemistry was also measured in addition to physiochemical characteristics as described above.

Statistical Analyses: Descriptive data were analyzed using both Bonferroni-corrected Pearson correlation statistics and multiple regression analyses. Independent variables (e.g., discharge, nutrient concentration, physiochemical characteristics) correlated with PPCP concentrations were used to develop predictive multiple regression models identifying factors controlling PPCP abundance. Multiple regression models were developed for all compounds with >60% detection frequency. Correlation and regression analyses informed development of predictive models using structural equation modeling. Structural equation modeling (SEM) was used to test *a priori* hypothesized causal pathways influencing pharmaceutical abundance and persistence in the environment. Data were modeled using SPSS statistical software equipped with AMOS17.0 (Amos v. 17.0 SPSS, Chicago, Illinois, USA). Data collected in conjunction with enrichment experiments were used to calculate PPCP transport metrics (uptake length, velocity, rate, retention, export) and compared among compound types using analysis of variance (ANOVA). Additionally, correlation and regression statistics were used to identify factors controlling retention and transport. All correlation, regression and ANOVA statistical analyses were performed using the SAS statistical program (SAS Institute, Inc.; System for Windows V8).

Table 1. Summary of physical, chemical and biological characteristics of streams sampled (N = 19) and pharmaceutical concentrations.

Physical Characterisitics	*Mean*	*SD*	Chemical Characteristics	*Mean*	*SD*	Biological Characteristics	*Mean*	*SD*	Pharmaceutical Abundance	*Mean*	*SD*
Light (% open)	26.3	19.9	Cl (mg/L)	47.6	20.5	SPOM (g/L)	0.018	0.016	Caffeine (ng/L)	37.8	29.5
pH	8.2	0.2	NO_3-N (mg/L)	3.4	4.0	CBOM (g/m^2)	6.5	9.2	Carbamazepine (ng/L)	20.1	25.2
Temperature ©	25.9	2.6	NH_4-N (mg/L)	0.1	0.1	MAC (g/m^2)	3.8	10.3	Cotinine (ng/L)	10.8	8.7
DO (mg/L)	6.5	1.4	DIN (mg/L)	3.5	4.0	FG (g/m^2)	46.2	64.7	Naproxen (ng/L)	5.6	2.3
TDS (g/L)	83.0	19.5	PO_4-P (mg/L)	0.4	0.3	FBOM (g/m^2)	294.6	344.4	Paraxanthine (ng/L	51.2	3.3
Wetted Width (m)	20.3	12.1	SO_4 (mg/L)	83.9	58.6	FBOM (% organic)	1.5	0.9			
Flow (m/s)	0.1	0.1	TC (mg/L)	96.8	23.3	EP (g/m^2)	3.7	6.0			
Depth (m)	0.38	0.23				Total Autrophic Biomass (g/m^2)	53.7	61.6			
Discharge (L/s)	1056	1410				Total Heterotrophic Biomass (g/m^2)	301.0	342.6			

Principle Findings:

Caffeine (24-135 ng/L), carbamazepine (1-88 ng/L), cotinine (4-34 ng/L), naproxen (5-15 ng/L), and paraxanthine (49-62 ng/L) concentrations varied among sites (Table 1). Correlation analyses identified multiple physical, chemical and biological stream characteristics related to pharmaceutical concentrations. Carbamazepine was positively correlated with nitrate (NO_3) and dissolved organic nitrogen (DIN) concentration ($p < 0.01$; Figure 1) as well as total dissolved carbon and temperature ($p < 0.05$) suggesting wastewater sources of PPCPs. Caffeine was positively correlated with macrophyte biomass as well as coarse benthic organic matter abundance and stream temperature ($p < 0.05$). Paraxanthine and naproxen were also positively correlated with macrophyte biomass ($p < 0.01$). Cotinine concentrations were not correlated with any measured variable ($p > 0.05$; data not shown).

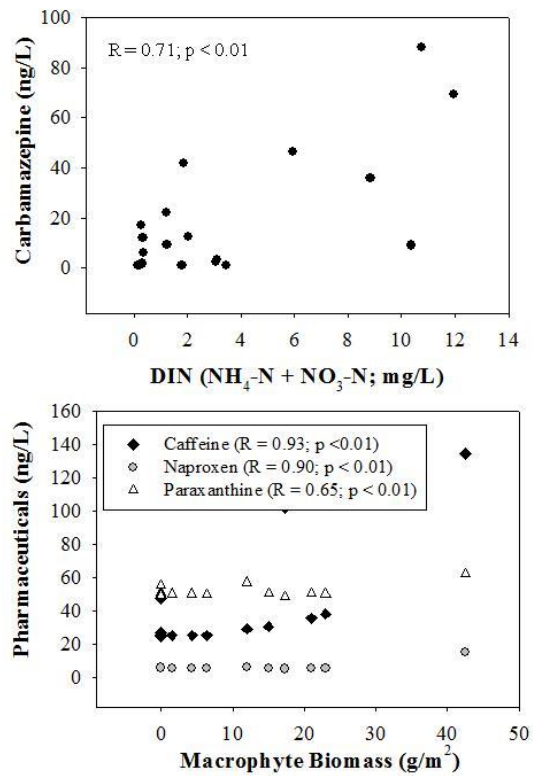

Figure 1. Correlations between dissolved inorganic nitrogen and carbamazepine (top panel) as well as macrophyte biomass and caffeine, naproxen and paraxanthine.

Multiple regression analyses explained > 95% of the variation in caffeine, cotinine, and naproxen concentrations but only 74% of the variation in carbamazepine and 58% of paraxanthine variation. Macrophyte biomass and DIN were the most consistent predictors of pharmaceutical concentrations across compounds though other physical and chemical characteristic were also explanatory including light, oxygen, flow, fine benthic organic matter, depth, and phosphate. Structural equation modeling (SEM) identified significant causal relationships between stream variables and total pharmaceutical concentration (sum of all measured compounds) with a significant fit of the covariance matrix (Figure 2). Significant pathways included flow and depth effects on discharge; discharge effects on ammonium; ammonium effects on total pharmaceutical concentrations; organic matter content on ammonium; and total dissolved solids on total pharmaceutical concentrations. Discharge and organic matter content of fine benthic material, though necessary for model fit, were not significant pathways explaining total pharmaceutical concentrations. Interestingly, light availability did not influence total pharmaceutical concentrations or autotrophic production (as biomass). Total autotrophic biomass yielded a better model fit than biomass of individual autotrophic compartments (macrophytes, epilithon, filamentous green algae.

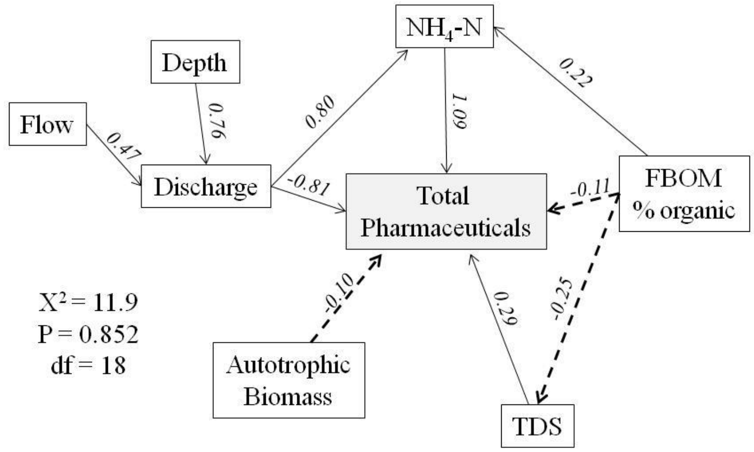

Figure 2. Structural equation model to describe controls on total dissolved pharmaceutical concentrations (sum of all pharmaceuticals measured) in central Indiana streams. Boxes are variables in the model. Numbers are standardized path coefficients. Error variance was calculated for all variables (not shown). Solid lines indicate significant paths in the model. Dashed lines denote hypothesized pathways not significant in the model but necessary for model fit. Model fit statistics noted.

Because carbamazepine was a dominant pharmaceutical measured in our descriptive study, we focused on carbamazepine for some additional analyses to understand potential organismal and ecosystem effects of this specific compound. Macroinvertebrate richness across study streams (N = 19) was positively correlated with increasing concentrations of carbamazepine (Figure 3). Using structural equation modeling (SEM) we inferred that carbamazepine influenced macroinvertebrate richness through indirect pathways linked to Baetidae abundance (data not shown). Baetidae abundance influenced ephemertopteran abundance and FBOM percent organic matter, both of which altered macroinvertebrate richness.

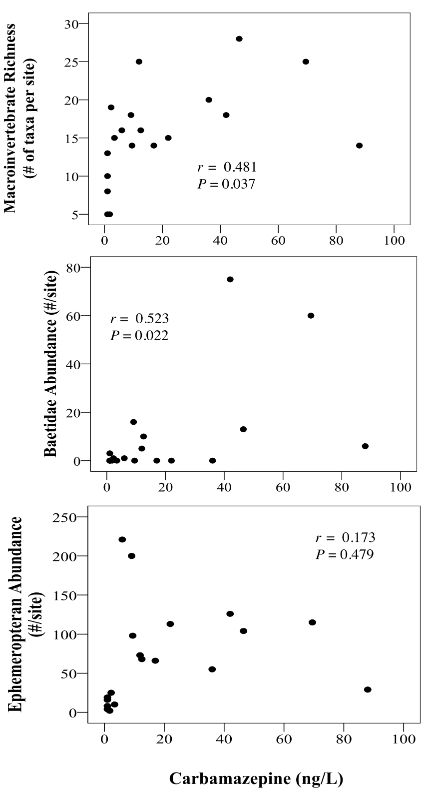

Figure 3. Bivariate correlations of carbamazepine (CBZ; ng/L), macroinvertebrate richness (# of taxa per site), and Baetidae and Ephemeroptera abundance (# of individuals per site). N = 19.

To better understand the effect carbamazepine has on life history characteristics of aquatic organisms and consumer-resource interactions, we assessed the influence of carbamazepine on the development, growth and behavior of mayfly nymphs (Stenonema sp.) and the alterations in food consumer-resource interactions between Stenonema and algae (Chaetophora) in laboratory microcosms. Carbamazepine influenced the development and behavior of Stenonema nymphs and the body dimensions of adult individuals (Figure 4). However, it appears that carbamazepine does not influence consumer-resource interactions at concentrations found in surface waters. The pharmaceutical carbamazepine may influence the behavior, growth and development of mayflies, which could have significant consequences at the population, community and ecosystem level.

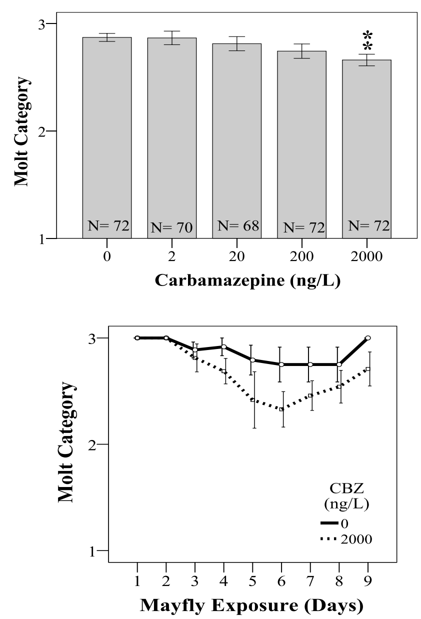

Figure 4. Molt category for mayfly nymphs exposed to carbamazepine (CBZ) treatments and molt category of mayfly nymphs over exposure (9 d) for control and 2000 ng/L CBZ treatment. Each data point represents the mean molt category for all *Stenonema* individuals in each treatment ± 1 SE. Categories ranged from 1-3, 1 being the newest molt and 3 the oldest. ** $P < 0.01$

Additionally, we conducted a 31 d *in situ* mesocosm experiment to quantify effects of environmentally-relevant concentrations of carbamazepine on invertebrate communities and ecosystem processes. Mesocosms were populated with four gastropod taxa (Elimia, Physa, Lymnaea and Helisoma), zooplankton, filamentous algae and phytoplankton. Invertebrate diversity increased in the presence of carbamazepine. Additionally, carbamazepine altered the biomass of Helisoma and Elimia, induced a decline in Daphnia pulex abundance and shifted the zooplankton community towards copepod dominance. Lastly, carbamazepine decreased decomposition and altered primary production and dissolved nutrient concentrations.

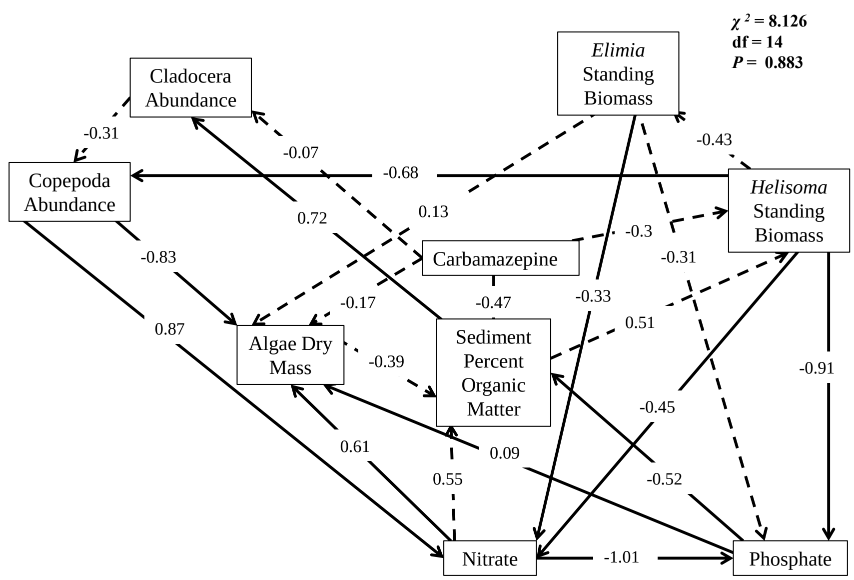

Figure 5. Structural equation model describing the relationship between carbamazepine and the freshwater ecosystem. The model ($\chi^2 = 8.126$, df = 14, $P = 0.883$) accounts for a substantial portion of the variability in the abiotic components of the ecosystem ($r > 0.50$). Numbers are standardized path coefficients. Solid lines indicate significant paths in the model ($P < 0.05$). Dashed lines are non-significant hypothesized pathways ($P > 0.05$).

Changes in the invertebrate community identified using structural equation modeling were through direct (i.e., exposure to carbamazepine) and indirect pathways (i.e., changes in food resource availability; Figure 5). These data show the psychiatric drug carbamazepine may alter freshwater community structure and ecosystem dynamics and could have profound effects on natural systems.

Laboratory chronic toxicity tests were also conducted to assess carbamazepine effects on yellow perch. Yellow perch growth (as increases in length and weight were negatively affected by carbamazepine concentrations. Additionally, yellow perch exposed to carbamazepine were less likely to respond to stimuli.

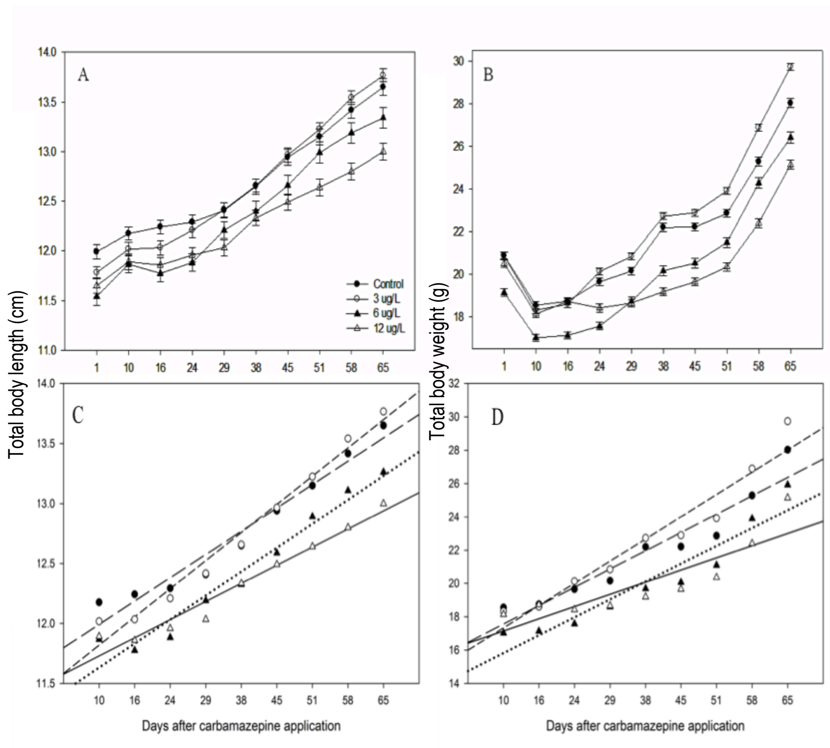

Figure 6. Change of total body length (A) and total body weight (B) of yellow perch after carbamazepine exposure. Symbols are mean +/- SE of three replicates per treatment. Slope difference of total body length (C) and body weight (D) among treatment groups with regression.

Significance

Overall, pharmaceutical concentrations detected in central Indiana streams were within the range previously documented in freshwaters throughout the United States though carbamazepine concentrations were ~5x higher than previous studies in central Indiana.
Consistent with previous studies in central Indiana, ammonium concentrations and stream discharge were not significant variables in correlation and regression analyses. However, structural equation models identified discharge and ammonium as important variables to model fit. These data characterized one time point (summer baseflow) when conditions likely yield lower pharmaceutical

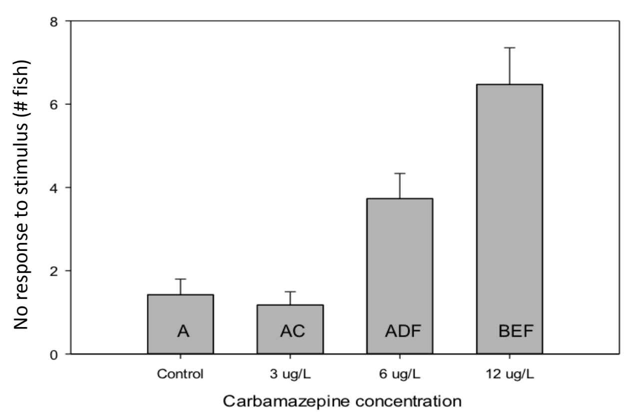

Figure 7. Carbamazepine effect on yellow perch behavior as response (movement) to stimulus after chronic exposure. Significant differences in stimulus response was measured at higher concentrations of carbamazepine ($p < 0.001$).

concentrations due to high potential for photo- and biodegradation as well as reduced input. This, coupled with higher autotrophic biomass in summer relative to other times of the year, suggests mechanisms controlling pharmaceutical abundance are temporally variable. Concentrations of pharmaceuticals measured in this study can influence aquatic organism reproduction and behavior. We found carbamazepine may alter the macroinvertebrate community structure of freshwater streams in central Indiana, which could potentially lead to alterations in resource availability (i.e., presence and use of FBOM) and predator-prey interactions (i.e., altered functional feeding groups present). *In vitro* experiments also demonstrated that environmentally relevant concentrations of carbamazepine could have chronic effects on Stenonema and Chaetophora. Further, an *in situ* mesocosm experiment demonstrate how environmentally relevant concentrations of carbamazepine alter the communities and processes of freshwater ecosystems.

Publications

Jarvis AL, MJ Bernot, RJ Bernot. *In review*. Relationships between the psychiatric drug carbamazepine and freshwater macroinvertebrate community structure. *Ecological Applications*. Submitted May 2014.

Jarvis, AL, MJ Bernot, RJ Bernot. *In review*. The effects of the pharmaceuticals carbamazepine on life history characteristics of flat-headed mayflies (Heptageniidae) and aquatic resource interactions. *Ecotoxicology*. Submitted April 2014.

Jarvis, AL, MJ Bernot, RJ Bernot. *In review*. The effects of the psychiatric drug carbamazepine on freshwater invertebrate communities and ecosystem dynamics: An *in situ* mesocosm experiment. *Ecological Applications*. Submitted May 2014.

Bernot, MJ, J Justice. *In press*. Survey of Personal Care Products (PCPs) in the United States. S. Díaz Cruz, D. Barceló (eds.). The Handbook of Environmental Chemistry: Personal Care Products in the Aquatic Environment. Springer.

Lee, JH, MJ Bernot. *In preparation*. The toxicity and effects of carbamazepine on Yellow Perch (*Perca flavescens*) growth and behavior. *Ecotoxicology*. To be submitted August 2014.

Abell, NS, MJ Bernot. *In preparation*. The influence of stimulants on the freshwater snail, *Physa acuta*. *Ecotoxicology*. To be submitted August 2014.

Bernot, MJ, RJ Bernot, LM Caffo, CL Crismore, D Elias, P Flores, J Justice, JH Lee, HL Madinger, and R Osborne. *In preparation*. Relationships between physiochemical characteristics, community structure and pharmaceutical concentrations in central Indiana streams. *Science of the Total Environment*. To be submitted August 2014.

Presentations

Bernot, MJ, AL Jarvis, RJ Bernot. 2014. Aquatic Neuroses: The effects of the pharmaceutical carbamazepine on aquatic ecosystem dynamics. Joint Aquatic Sciences Meeting, Portland, OR. May.

Lee, JH, MJ Bernot. 2014. The toxicity and effects of carbamazepine on Yellow Perch (*Perca flavescens*) growth and behavior. Ball State University Student Symposium. March.

Abell, NS, MJ Bernot. 2014. The influence of stimulants on the freshwater snail, *Physa acuta*. Ball State University Student Symposium. March.

Lee, JH, MJ Bernot. 2013. Invited Seminar. Transfer of 17a-ethynylestradiol and carbamazepine in a food chain established by invasive species: Toxicity, pharmacokinetics and bioaccumulation. Taylor University, Department of Chemistry. October 2013.

Bernot, RJ, MJ Bernot, LM Caffo, CL Crismore, D Elias, P Flores, J Justice, JH Lee, HL Madinger, R Osborne. 2013. Parasites as indicators of drug contamination: relationships among parasites, gastropods and pharmaceuticals in Midwestern streams. American Society for Parasitology. Québec City, Québec.

Jarvis, A, MJ Bernot, RJ Bernot. 2013. The effects of the pharmaceutical carbamazepine on aquatic macroinvertebrate community structure. Indiana Water Resources Association, Muncie. June.

Bernot, MJ, RJ Bernot, LM Caffo, CL Crismore, D Elias, P Flores, J Justice, JH Lee, HL Madinger, R Osborne. 2013. Relationships between physiochemical characteristics, community structure and pharmaceutical concentrations in central Indiana streams. Society for Freshwater Science, Jacksonville, FL. May.

Jarvis, A, MJ Bernot, RJ Bernot. 2013. The effects of the pharmaceutical carbamazepine on aquatic macroinvertebrate community structure. Society for Freshwater Science, Jacksonville, FL. May.

Lee, JH, MJ Bernot. 2013. Transfer of 17a-ethynylestradiol and carbamazepine in a food chain established by invasive species: Toxicity, pharmacokinetics and bioaccumulation. Ball State University Student Symposium. March.

Jarvis, A, MJ Bernot, RJ Bernot. 2013. The effects of the pharmaceutical carbamazepine on aquatic macroinvertebrate community structure. Ball State University Student Symposium. March.

Jarvis, AL, MJ Bernot, RJ Bernot. 2013. The effects of the pharmaceutical carbamazepine on aquatic macroinvertebrate community structure. Indiana Academy of Science, Indianapolis. March.

Drosos, I, MJ Bernot. 2013. Factors influencing anion loss and retention in sediment. Ball State University Student Symposium. March.

Thesis

Jarvis, AL. The effects of the psychiatric drug carbamazepine on freshwater invertebrate communities and ecosystem dynamics. MS Thesis. Ball State University, May 2014.

Grant Submissions

Lee, JH. *Funded*. 2014-2015. Assessing acute and chronic toxicity of carbamazepine and 17α-ethynylestradiol on yellow perch (*Perca flavescens*). Indiana Academy of Science Senior Research Grant. Total Award: $2,914.

Lee, JH. *Funded*. 2014-2015. Assessing acute and chronic toxicity of carbamazepine and 17α-ethynylestradiol on yellow perch (*Perca flavescens*) BSU ASPiRE Graduate Research Program. Total Award: $500.

Drosos, I. *Funded*. 2014-2015. Carbamazepine loss and retention in sediments. Ball State University ASPiRE Undergraduate Student Research. Total Award: $300.

Becker, JC, MJ Bernot, TE Lauer. 2014-2015. *Funded.* RiverPACE: A Nationwide Riverine Pharmaceuticals Assessment, Collection, and Education Project. Discovery Group. Total Award: $19,972.

Bernot, MJ, RJ Bernot, J Becker, K Epp. *In review*. A systems-based approach to quantify abundance, fate and effects of pharmaceuticals and personal care products (PPCPs) in lotic ecosystems. Environmental Protection Agency (EPA-G2014-STAR-E1): Systems-Based Research for Evaluating Ecological Impacts of Manufactured Chemicals. Total Request: 799,523. Submitted March 2014.

Bernot, MJ, RJ Bernot. Not Funded. Preliminary Proposal: RUI: Predicting abundance, transport and effects of PPCPs in lotic ecosystems in a changing world. National Science Foundation Division of Environmental Biology. Submitted January 2014.

Bernot, MJ. Not funded. Water Environment Research Foundation Unsolicited Research Program. Freshwater Pharmaceutical and Personal Care Product Risk Management. Submitted August 2013.

Bernot, MJ. Not funded. Occurrence of pharmaceuticals in freshwater: Quantifying human exposure to trace contaminants. National Institute of Health. Submitted October 2013.

Students

A total of 3 graduate students and 4 undergraduate students were involved with project activities.

Graduate Students (Ball State University): Amanda Jarvis, MS student; Jee Hwan Lee, PhD student; Courtney Crismore, MS student
Undergraduate Students (Ball State University, BS Biology students): Natalie Abell, Isis Drosos, Susannah Dragash, Nicole Woodall

Estimating Capture Probabilities of Common Stream Fish in the Eastern Corn Belt Plain

Basic Information

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Principal Investigators:	Thomas E Lauer, Jason C Doll

Publications

1. None yet
2. None yet

ESTIMATING CAPTURE PROBABILITIES OF COMMON STREAM FISH IN THE EASTERN CORN BELT PLAIN

Prepared By:
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May, 2014

Abstract:

Imperfect detection of fish can lead to biased estimates of abundance and assemblage level descriptors such as the Index of Biotic Integrity. Accentuating this bias are two items. First the schooling behavior of fish confounds the efficacy of traditional models in estimating abundance and capture probability. Second, we know habitat influences fish distribution and catchability. Although multi-pass depletion sampling of fish can be used to estimate some of the bias, assuming fish behave independently, quantifying both schooling and habitat bias effects is required to fully understand fish abundance. Thus, our objective in this study is to determine how imperfect detection of common stream fishes is influenced by schooling behavior and a suite (14) of physicochemical variables. To meet this objective, we conducted multi-pass depletion surveys at 16 randomly selected sites in the Eastern Corn Belt Plain ecoregion in Indiana. A total of 1,193 fish representing 65 species were sampled during the project. We will use these data and extend an existing model to estimate abundance and capture probability of schooling and non-schooling species. These estimated capture probabilities can then be applied to standard electrofishing surveys to improve the accuracy of abundance estimates and can be applied to biological monitoring tools to create multimetric indices that are more sensitive to perturbation.

Problem and Research Objectives:

Stream health can be assessed using multimetric indices, such as the Index of Biotic Integrity (IBI), and multivariate analysis (ter Braak 1986; Karr 1991). The IBI has been used to assess the health of Indiana's streams in the Eastern Corn Belt Plain for over a decade (Simon & Dufour 1997). This multimetric index and other similar ones were patterned after Karr (1981) and have been widely used and accepted. Unfortunately, the sensitivity in detecting shifts in fish assemblages using an IBI is restricted to major perturbations (Trebitz et al. 2003). Improvements in describing stream health and improving sensitivity are possible using other methods, such as multivariate analysis (Thomas & Hall 2006), but typically require different, or more extensive data. One such factor limiting sensitivity in the IBI is our ability to obtain accurate estimates of fish abundance as capture probability is influenced by environmental variables. By refining something this basic with respect to capture (e.g., reduce variability), we will advance our ability to detail stream health, regardless of the multimetric method employed in the analysis.

Obtaining accurate estimates of fish abundance in streams are problematic. Standard sampling methods for an IBI (Simon & Dufour 1997) typically consists of single pass electrofishing catch per unit effort as an index of abundance. This method assumes the probability of capturing a fish is 1 (i.e., perfect capture probability), capture probability is spatially constant, and equal among species. These assumptions are not ecologically reasonable and often violated, thereby increasing bias, adding noise to the dataset and limiting our ability to detect change. Variability in capture probabilities can also be exaggerated due to fluctuations in physicochemical factors. For example, differences in conductivity and turbidity across disparate waters could influence capture efficacy, limiting our ability to describe whether differences in the fish assemblage exist. The need to evaluate factors influencing capture probabilities is real and must be resolved to improve our understanding of the fish community. Ultimately, this study will lead to better fisheries management decisions and evaluation of water quality through biological interpretation not just in the Eastern Corn Belt Plain, but elsewhere.

Our objective is twofold: 1. Determine capture probabilities of common stream fishes in wadeable streams of the Eastern Corn Belt Plain while accounting for schooling behavior, and 2. determine how variation in physicochemical parameters among the streams may influence capture probabilities. To meet these objectives we will conduct multi-pass depletion surveys (both fish and physicochemical parameters) at a minimum of 25 randomly selected sites and use the data to model factors influencing capture probabilities of fishes. We will also extend the models of Royle (2004) for non-schooling species and Martin et al. (2011) for schooling species to account for covariates of detection. We hypothesize that the physicochemical parameters being measured will significantly affect capture probabilities of fishes in wadeable streams of the Eastern Corn Belt Plain. We also hypothesize that not accounting for schooling behavior will bias capture probabilities and abundance estimates of schooling species.

Methodology:

Sixteen sites were sampled between June 19 and August 8, 2013. Each site was closed off with a block net placed at the upstream and downstream ends to restrict fish movement during the survey. Three passes with a tote-barge DC electrofishing unit were conducted in an upstream pattern. At the end of each pass, fish were counted and held in large tanks until the survey was completed. Species that required visual examination under a dissecting microscope were preserved in formalin on site and transported to Ball State University. Methodology has been approved by the Ball State University Animal Care and Use Committee (IACUC Protocol #:317058-1).

Fourteen physicochemical parameters were collected at each site to evaluate their influence on capture probabilities (conductivity, turbidity, stream width, water temperature, average depth, stream gradient, habitat type (pool, riffle, run, glide), and substrate type (fines, gravel, cobble, boulder). Conductivity, water temperature, and turbidity were measured with a Hydrolab DS5 probe with a Hach Trimble Recon field computer. Stream width and sampling distance was measured with a laser range finder. Average depth was measured by taking depth measurements at seven equidistant points along a transect. Transects were spaced every 10 m. Stream gradient will be measured using USGS topographic maps. Habitat was further assessed at each site using the Qualitative Habitat Evaluation Index (Rankin 1989).

Principle Findings:

A total of 1,193 fish representing 65 species were sampled during the project. Species diversity at individual sites ranged from 18 to 37 species. The most diverse sites were Wildcat Creek (37 species), Whitewater River (32 species), and Nolan's Fork (29 species). The relationship between the physicochemical parameters and QHEI metrics on detectability will be analyzed in the coming months.

Significance:

This project will determine capture probabilities of common stream fish sampled throughout the Eastern Corn Belt Plain. The influence of fish schooling behavior and commonly measured physicochemical variables will be incorporated into the model to provide more accurate estimates of abundance. By accounting for these confounding variables, sensitivity in secondary data summaries (e.g., multimetric indices) will increase the ability to detect perturbations. The results will not only provide a methodology to improve our interpretation of water quality using multimetric indices, but also benefit managers and researchers nationwide in obtaining the best possible estimates of species abundance.

Publications:

The project is ongoing and the data are still being analyzed. We anticipate one presentation at the 2015 Midwest Fish and Wildlife conference in Indianapolis and one manuscript submitted for publication.

Grant Submissions: None

Students:

Four graduate students conducted all field work.

One graduate student and two undergraduate students identified fish in the lab.

References Cited:

Karr, J.R. 1981. Assessment of biotic integrity using fish communities. Fisheries 6:21-27.

Martin, J., J.A. Royle, D.I. Mackenzie, H.H. Edwards, M. Kery, & B. Gardner. 2011. Accounting for non-independent detection when estimating abundance of organisms with a Bayesian approach. Methods in Ecology and Evolution 2:595-601.

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Trebitz, A.S., B.H. Hill, & F.H. McCormick. 2003. Sensitivity of indices of biotic integrity to simulated fish assemblage changes. Environmental Management 32(4):499-415.

Linking Cover Crops to Improved Stream Water Quality via Field-Scale Soil Sampling, in Shatto Ditch Watershed, IN

Basic Information

Title:	Linking Cover Crops to Improved Stream Water Quality via Field-Scale Soil Sampling, in Shatto Ditch Watershed, IN
Project Number:	2013IN362B
Start Date:	3/1/2013
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	IN-001, IN-002
Research Category:	Biological Sciences
Focus Category:	Nitrate Contamination, Non Point Pollution, Surface Water
Descriptors:	
Principal Investigators:	Jennifer L Tank, Sheila F Christopher

Publications

1. None yet
2. None yet

ESTIMATING CAPTURE PROBABILITIES OF COMMON STREAM FISH IN THE EASTERN CORN BELT PLAIN

Prepared By:
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Muncie, IN 47306

May, 2014

Abstract:

Imperfect detection of fish can lead to biased estimates of abundance and assemblage level descriptors such as the Index of Biotic Integrity. Accentuating this bias are two items. First the schooling behavior of fish confounds the efficacy of traditional models in estimating abundance and capture probability. Second, we know habitat influences fish distribution and catchability. Although multi-pass depletion sampling of fish can be used to estimate some of the bias, assuming fish behave independently, quantifying both schooling and habitat bias effects is required to fully understand fish abundance. Thus, our objective in this study is to determine how imperfect detection of common stream fishes is influenced by schooling behavior and a suite (14) of physicochemical variables. To meet this objective, we conducted multi-pass depletion surveys at 16 randomly selected sites in the Eastern Corn Belt Plain ecoregion in Indiana. A total of 1,193 fish representing 65 species were sampled during the project. We will use these data and extend an existing model to estimate abundance and capture probability of schooling and non-schooling species. These estimated capture probabilities can then be applied to standard electrofishing surveys to improve the accuracy of abundance estimates and can be applied to biological monitoring tools to create multimetric indices that are more sensitive to perturbation.

Problem and Research Objectives:

Stream health can be assessed using multimetric indices, such as the Index of Biotic Integrity (IBI), and multivariate analysis (ter Braak 1986; Karr 1991). The IBI has been used to assess the health of Indiana's streams in the Eastern Corn Belt Plain for over a decade (Simon & Dufour 1997). This multimetric index and other similar ones were patterned after Karr (1981) and have been widely used and accepted. Unfortunately, the sensitivity in detecting shifts in fish assemblages using an IBI is restricted to major perturbations (Trebitz et al. 2003). Improvements in describing stream health and improving sensitivity are possible using other methods, such as multivariate analysis (Thomas & Hall 2006), but typically require different, or more extensive data. One such factor limiting sensitivity in the IBI is our ability to obtain accurate estimates of fish abundance as capture probability is influenced by environmental variables. By refining something this basic with respect to capture (e.g., reduce variability), we will advance our ability to detail stream health, regardless of the multimetric method employed in the analysis.

Obtaining accurate estimates of fish abundance in streams are problematic. Standard sampling methods for an IBI (Simon & Dufour 1997) typically consists of single pass electrofishing catch per unit effort as an index of abundance. This method assumes the probability of capturing a fish is 1 (i.e., perfect capture probability), capture probability is spatially constant, and equal among species. These assumptions are not ecologically reasonable and often violated, thereby increasing bias, adding noise to the dataset and limiting our ability to detect change. Variability in capture probabilities can also be exaggerated due to fluctuations in physicochemical factors. For example, differences in conductivity and turbidity across disparate waters could influence capture efficacy, limiting our ability to describe whether differences in the fish assemblage exist. The need to evaluate factors influencing capture probabilities is real and must be resolved to improve our understanding of the fish community. Ultimately, this study will lead to better fisheries management decisions and evaluation of water quality through biological interpretation not just in the Eastern Corn Belt Plain, but elsewhere.

Our objective is twofold: 1. Determine capture probabilities of common stream fishes in wadeable streams of the Eastern Corn Belt Plain while accounting for schooling behavior, and 2. determine how variation in physicochemical parameters among the streams may influence capture probabilities. To meet these objectives we will conduct multi-pass depletion surveys (both fish and physicochemical parameters) at a minimum of 25 randomly selected sites and use the data to model factors influencing capture probabilities of fishes. We will also extend the models of Royle (2004) for non-schooling species and Martin et al. (2011) for schooling species to account for covariates of detection. We hypothesize that the physicochemical parameters being measured will significantly affect capture probabilities of fishes in wadeable streams of the Eastern Corn Belt Plain. We also hypothesize that not accounting for schooling behavior will bias capture probabilities and abundance estimates of schooling species.

Methodology:

Sixteen sites were sampled between June 19 and August 8, 2013. Each site was closed off with a block net placed at the upstream and downstream ends to restrict fish movement during the survey. Three passes with a tote-barge DC electrofishing unit were conducted in an upstream pattern. At the end of each pass, fish were counted and held in large tanks until the survey was completed. Species that required visual examination under a dissecting microscope were preserved in formalin on site and transported to Ball State University. Methodology has been approved by the Ball State University Animal Care and Use Committee (IACUC Protocol #:317058-1).

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Principle Findings:

A total of 1,193 fish representing 65 species were sampled during the project. Species diversity at individual sites ranged from 18 to 37 species. The most diverse sites were Wildcat Creek (37 species), Whitewater River (32 species), and Nolan’s Fork (29 species). The relationship between the physicochemical parameters and QHEI metrics on detectability will be analyzed in the coming months.

Significance:

This project will determine capture probabilities of common stream fish sampled throughout the Eastern Corn Belt Plain. The influence of fish schooling behavior and commonly measured physicochemical variables will be incorporated into the model to provide more accurate estimates of abundance. By accounting for these confounding variables, sensitivity in secondary data summaries (e.g., multimetric indices) will increase the ability to detect perturbations. The results will not only provide a methodology to improve our interpretation of water quality using multimetric indices, but also benefit managers and researchers nationwide in obtaining the best possible estimates of species abundance.

Publications:

The project is ongoing and the data are still being analyzed. We anticipate one presentation at the 2015 Midwest Fish and Wildlife conference in Indianapolis and one manuscript submitted for publication.

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Quantifying the seasonal change in the geochemical state of the Wabash River using

Basic Information

Title:	Quantifying the seasonal change in the geochemical state of the Wabash River using
Project Number:	2014IN369B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	04
Research Category:	Not Applicable
Focus Category:	Agriculture, Hydrology, Management and Planning
Descriptors:	None
Principal Investigators:	Keith Aric Cherkauer, Indrajeet Chaubey

Publication

1. No Publications

IWRRC 2015 Project Reports (Information needed by June 1, 2015)

Project Id: 2014IN369B

Title: Quantifying the seasonal change in the geochemical state of the Wabash River using remote sensing

Project Type: Research

Start Date: 3/1/2014 **End Date:** 2/28/2015

Congressional District: 04

Focus Categories: AG, HYDROL, M&P, NPP, NU, SED, SW, WQL

Keywords: water quality, remote sensing, sediment transport, Wabash River

Principal Investigators:

Keith Cherkauer, Associate Professor, Department of Agricultural and Biological Engineering, Purdue University, IN. email:cherkaue@purdue.edu phone:765-496-7982

Indrajeet Chaubey, Professor, Department of Agricultural and Biological Engineering, Department of Earth, Atmospheric, and Planetary Sciences, Purdue University, IN. email:ichaubey@purdue.edu phone:765-494-5013

Abstract / Summary

Water quality is a major issue for rivers in the agriculturally dominated Midwestern United States. Most monitoring of water quality relies on the installation of expensive real-time monitoring stations or the selection of permanent sampling sites where samples are collected by hand, which is often expensive, labor-consuming and spatially and/or temporally limited. While remote sensing has been widely used to quantify optically active constituents (OACs) in open oceans, coastal areas and lakes due to its great spatial and temporal coverage, it is still limited in riverine systems due to both the coarse resolution of satellite sensors and the challenge of estimating OACs using empirical modeling methods. Physical models based on the radiative transfer process within the water column and with consideration of all OACs at one time have been little used in river systems due the required investment in hardware and software. The lack of inherent optical properties (IOPs) measurements is another limitation of developing physical models for inland waters. This project will continue the development of a database with measurements of the geochemical state of the Wabash River and Tippecanoe River and coincident spectral reflectance measurements. As part of this project, we will collect high-resolution spectral data over the two rivers using Unmanned Aerial Vehicles (UAVs), and will use all data in the development and evaluation of physical radiative transfer models relating spectral properties to the geochemical state of the river system. Such models should be better able to estimate the geochemical state of the river from remote sensing imagery, and more transferable to other locations. We expect this project to result in a database of IOP and water quality measurements of the Wabash River under various environmental conditions and algorithms that are effective for the remote sensing of the Wabash River and other major Midwestern rivers.

Problem

Excess concentrations of sediment and nutrients originating from agricultural activities are two primary sources of water quality impairment in the rivers of the Midwestern United States (Brown and Froemke, 2012; National Research Council, 2008). Midwestern rivers, especially in Indiana, are also major contributors to downstream problems in water quality, especially the hypoxic zone in the Gulf of Mexico (Burkhart and James, 1999). Remote sensing has advantages over traditional in-situ measurements for monitoring water quality since it can provide synoptic water quality information over a great range of temporal and spatial scales. While remote sensing has been widely used to quantify optically active constituents (OACs) in open oceans, coastal areas and lakes (e.g., Brando and Dekker, 2003), its use is still limited in riverine systems due to both the coarse resolution of satellite sensors and the challenge of estimating OACs in shallow waters. Traditional empirical methods are not based on any physical insight into why correlations exist between optical properties and geochemical state and are highly dependent on the data used and often not repeatable or transferrable. The fact that OACs do not covary (IOCCG, 2000) and that bottom reflectance is often non-negligible in inland waters is also likely to result in significant errors in empirical models. The physical modeling approach is based on the radiative transfer processes within the water column with consideration of all OACs simultaneously. Such models have been well tested for open oceans, lakes and reservoirs; however, little attention has been paid to river systems, even though what happens in lakes and ocean coastal waters is highly dependent on these systems. The lack of measurements of inherent optical properties (IOPs) for inland waters and application of appropriate modeling software are important aspects limiting the development of physical models.

Research Objectives

The primary objective for this research is to develop an extensive database of coincident measurements of spectral characteristics and geochemical state for water in the Wabash River and its tributaries, which can be used to develop physical models to estimate the geochemical state of the river water from remote sensing imagery for different flow regimes and seasons. Specific research hypotheses that will be addressed are:

1. ***Physical radiative transfer models developed using measurements of spectral characteristics and geochemical state from different seasonal flow regimes will provide more accurate and robust predictions of the river system's state than more traditional methods.***
2. ***High-resolution spectral and thermal imagery when combined with physical radiative transfer models can provide new insights into the movement and sources of chemicals in the river system.***

Methodology

In-situ water quality and spectrometer sampling, Task 1

We have worked with Dr. Reuben Goforth and his research group in the department of Forestry and Natural Resources at Purdue University to schedule our boat sampling trips into their field work timeline. Regular weekly boat sampling (grabbing water samples, spectral measurements, water depth measurements, sonde measurements, and GPS locations) were conducted along the Wabash River and the Tippecanoe River from May, 2014 to August, 2014. Above water spectral measurements were collected using the optimal measuring geometry suggested by NASA's standard operating protocol of satellite ocean color remote sensing. A GoPro camera was also purchased to record bottom type of sampled sites. Albedos of various river bottom types were collected during low flow conditions when streambed emerged, and related back to the classification of streambed materials from the GoPro camera images.

During the 2014 sampling period, we completed a regular sampling procedure on a total of 28 dates, resulting in a total of 213 sites where water samples were collected. Figure 1 shows the measured reflectance spectra and bottom albedo. Bottom types identified for the Wabash River and the Tippecanoe River are shown in Figure 2.

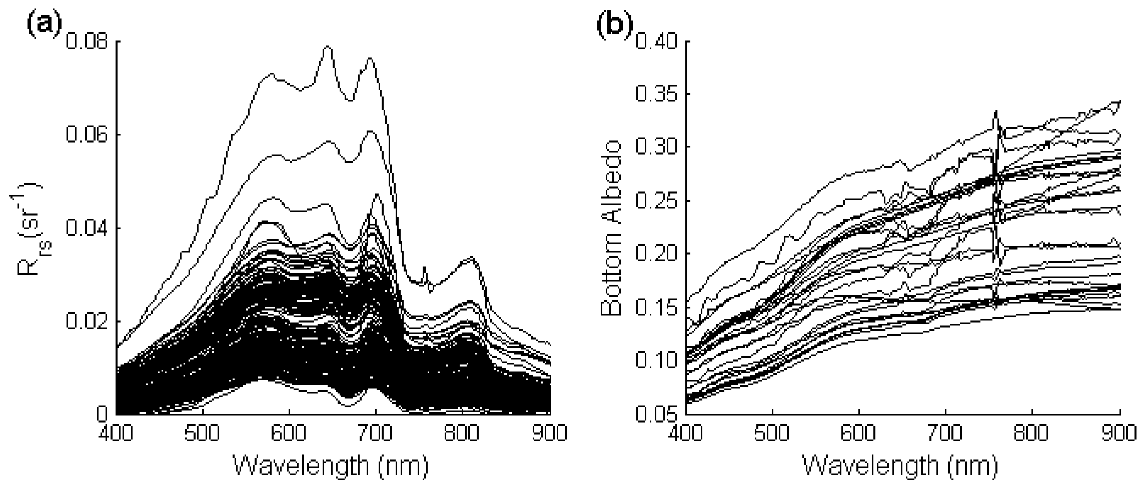

Figure 1. (a) Field measured remote sensing reflectance (R_{rs}) spectra and (b) bottom albedo for different bottom types.

Figure 2. Bottom types identified for the Wabash River and the Tippecanoe River.

Lab analyses of OACs, nutrients and IOPs, Task 2

All water samples were analyzed in the lab for concentrations of total suspended solids, chlorophyll, and nutrients (orthophosphate, nitrate+nitrite nitrogen, total nitrogen, total phosphorus, and dissolved organic carbon) using EPA approved standard methods of analyses. Table 1 lists the statistics of 2014 lab results for the Wabash River and Tippecanoe River. In addition, inherent optical properties (IOPs) including the absorption coefficients of chlorophyll, non-algal particles, and colored dissolved organic carbon were analyzed according to NASA's protocol of satellite ocean color remote sensing (Figure 3).

Table 1. Statistics of lab measured OACs and nutrients for the Wabash River and the Tippecanoe River.

	OACs		Nutrients				
	TSS (g/m^3)	CHL (mg/m^3)	oPO_4 (mg/l)	NO_x (mg/l)	TN (mg/l)	TP (mg/l)	DOC (mg/l)
Max	102.0	175.3	0.093	9.7	10.6	0.472	41.5
Mean	36.6	51.8	0.010	5.1	6.0	0.094	26.9
Min	8.5	8.3	-0.028	0.3	1.3	0.014	8.1

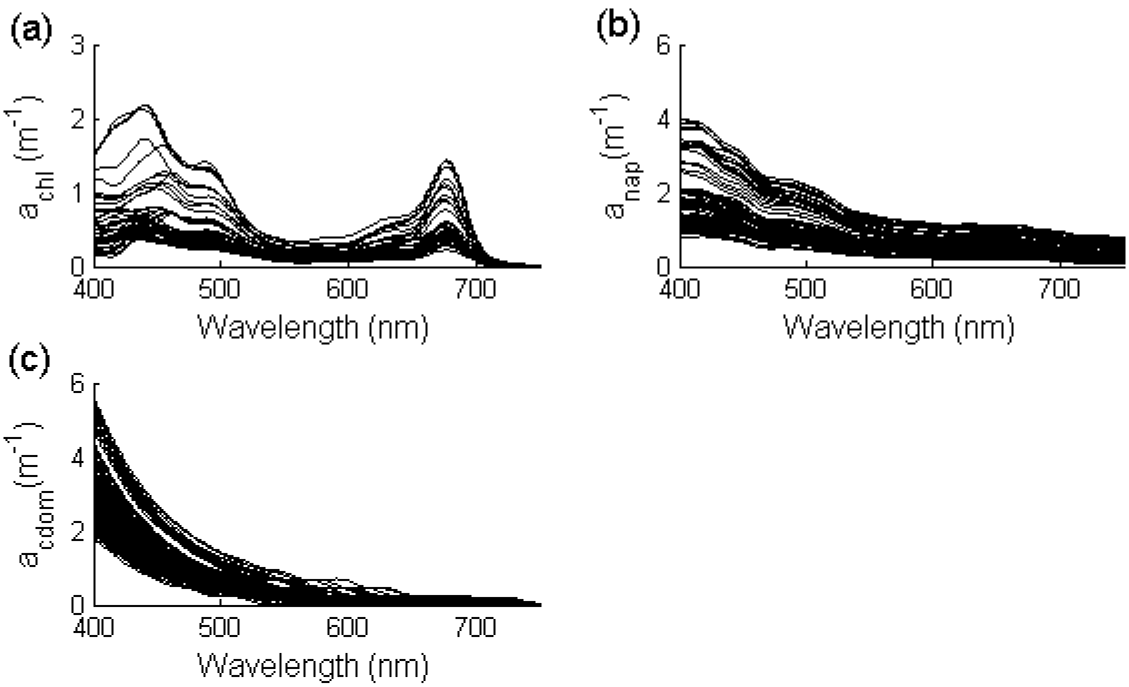

Figure 3. Lab measured absorption coefficients of (a) chlorophyll, (b) non-algal particles, and (c) colored dissolved organic matter.

Remote sensing data collection, Task 3

Purdue University has obtained a Certificate of Authorization (COA) from the FAA that gives us authority to operate Unmanned Aerial Vehicles (UAVs) in our study area for water quality monitoring. We have also obtained a special operating permit from Prophetstown State Park to use park property near the confluence of the Tippecanoe River and Wabash River as a base of operations for UAV flights. In the summer of 2015 we will arrange to have project participants work to collect both in-situ water quality and spectrometer data (Task 1) coincident with scheduled image acquisitions from UAV platforms. Field spectrometer measurements will be collected within a short time window of image acquisition and serve as the validation data for atmospheric correction of acquired UAV images. In addition to the multispectral imagery collected by our own UAV platforms from PrecisonHawk Inc, we will also partner with Dr. Melba Crawford to acquire hyperspectral imagery using their UAV system, which is integrated with a hyperspectral sensor from Headwall Photonics.

Model development and validation, Task 4

The radiative transfer software package Hydrolight was purchased and used to develop physical models for the Wabash River and the Tippecanoe River. Analysis was conducted on the field observations and lab measurements collected in Task 1 and Task 2. A database of Hydrolight-simulated reflectance spectra was assembled. By finding the closest match of the field measured spectrum in the database, water quality parameters including chlorophyll and TSS were successfully retrieved (Figure 4).

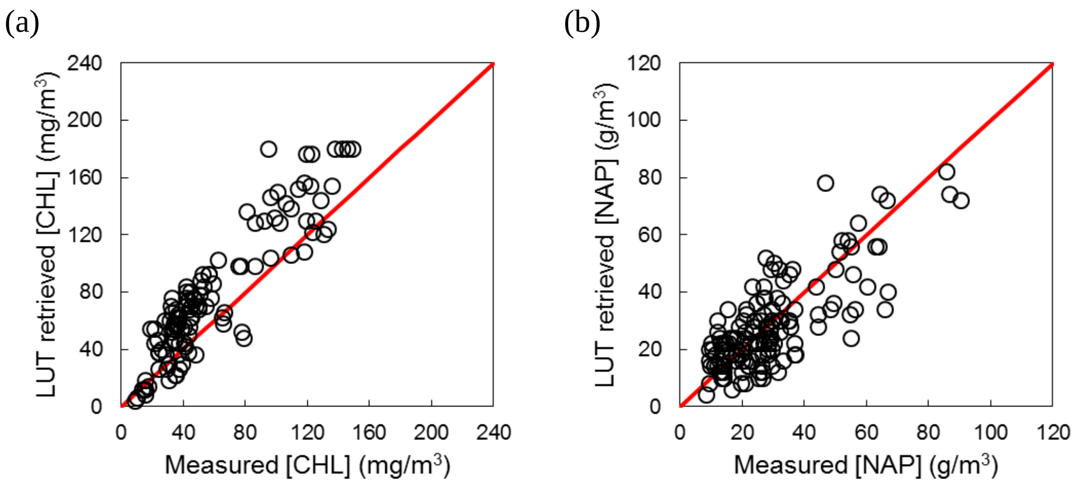

Figure 4. Comparison between field measured (a) chlorophyll concentration ([CHL]) and (b) TSS concentration ([TSS]) and the LUT estimates for the Wabash River and the Tippecanoe River

The UAV imagery collected in Task 3 will be georegistered (Turner et al., 2012) and calibrated to remote sensing reflectance. The hyperspectral LUTs generated above will be further synthesized into UAV sensors' wavelengths so that concentrations of OACs can still be estimated or looked up by comparing the satellite imagery derived reflectance to the LUTs. Data that are not used in model developments will be used for model evaluation.

Results

We have successfully collected in-situ water quality and spectrometer data of the Wabash River and the Tippecanoe River under various hydrological conditions. Water quality data we collected in 2014 show large variations (e.g. TSS ranges from 9 g/m^3 to 100 g/m^3 and chlorophyll from 8 mg/m^3 to 175 mg/m^3). Absorption properties of water quality parameters were also acquired. The measurements of water quality and IOPs, when combined with climate and hydrologic flow regime, enable a better understanding of the geochemical state of Midwestern waters. These field measured data were analyzed and used to develop physical radiative transfer models for the Wabash River. The LUT methodology relates observed spectral reflectance to water column and bottom properties

(Mobley et al., 2005) and was successfully applied to the field data for the retrieval of water quality parameters. We will continue our efforts in the summer of 2015 to get UAV imagery over the study area, which will provide a synoptic view of water quality conditions. The ability of UAV images for water quality monitoring will be evaluated.

All lab results, together with field measurements, were assembled into a database for storage and management using Microsoft Access. This database is currently stored on Purdue ECN network drive, which is backed up daily. Only authorized users have access to the database and the database is protected by password. Remote sensing imagery and the Hydrolight-simulated LUT will also be integrated into the database in the future. Once the database is completed, it will be published through the Purdue University Research Repository (PURR) and assigned a DOI number for distribution.

Major Conclusions and Significance

Water quality is a major concern on the Wabash River and other agriculturally dominated river systems in the United States and globally. Understanding the sources of water quality problems, and how water quality varies temporally and spatially are important for monitoring existing problems and the effectiveness of best management practices (BMPs) currently being employed. Remote sensing has the potential to provide synoptic water quality information of inland rivers and lakes. However, the ability of satellite remote sensing for inland water monitoring has been hampered by coarse spatial resolutions and lack of IOP measurements for the development of physical models. In order to improve remote sensing of water quality for inland waters, filed measurements of reflectance spectra, water quality, and IOPs under different hydrologic conditions are needed, which will enable the development of physical models for the Wabash River and provide a fundamental linkage between the optical properties and the geochemical state of inland waters. The application of high-resolution UAV imagery, once succeeded, will provide an effective way for water quality monitoring of inland rivers. This database developed in this study will deliver algorithm recommendations for remote sensing of water quality in shallow inland waters, provide useful inputs for future projects on nutrients cycling and ecosystem modeling as well as provide valuable sources for further investigation of the relationship between optical and geochemical properties.

Publications

Tan, J., K. A. Cherkauer, and I. Chaubey, 2015. Using hyperspectral data to quantify water quality parameters in the Wabash River and its tributary, Indiana. Submitted to *International Journal of Remote Sensing*.

Grant Submissions

NASA Earth and Space Science Fellowship, Funded, “Developing a comprehensive spectral-biogeochemical database of Midwestern waters for improving remote sensing of water quality”

Students

Jing Tan, Ph.D., ABE

Reconnection of floodplain lakes in the Patoka River watershed: habitat and fish assemblages

Basic Information

Title:	Reconnection of floodplain lakes in the Patoka River watershed: habitat and fish assemblages
Project Number:	2014IN370B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	006
Research Category:	Not Applicable
Focus Category:	Ecology, Geomorphological Processes, Hydrogeochemistry
Descriptors:	None
Principal Investigators:	Mark Pyron

Publications

There are no publications.

General Report Format

Report Format

Cover Page---

Project Id:

Title: Reconnection of floodplain lakes in the Patoka River watershed: habitat and fish assemblages

Project Type: Research

Start Date: 3/01/2014 **End Date:** 2/28/2015

Congressional District: IN-006

Focus Categories: ECL, GEOMOR, HYDGEO, HYDROL, SED

Keywords: Fish assemblages, floodplain lakes, river hydrology

Principal Investigators: Mark Pyron

Abstract / Summary: Floodplain lakes in the Patoka River National Wildlife Refuge (NWR) were isolated with a historical dredging project. This project has a longterm goal of restoring a natural flooding regime to these floodplain lakes by removing levees in the refuge. The current project provides background data for fish assemblages prior to modifications. Fishes were collected at 11 floodplain lakes in the Patoka River NWR in September 2014. Collections were by backpack and tote barge electrofishers. Collections resulted in 257 individuals in 22 species. Mean species richness at sites was 5 and ranged from 1-11. Mean site abundance was 23.4 individuals, and ranged from 1 – 74. Fish assemblages were predictable based on maximum depth and distance to the river. These collections provide background data to compare with following restoration by levee removal in the future.

Problem: Floodplain habitats are essential for ecosystem functioning in lowland rivers (Galat et al. 1998). These habitats are maintained by predictable connection with mainstem rivers. Maintaining floodplain habitats allows recurrent connections with the mainstem to permit colonization and prevent sediment filling. Predictable flood events are part of the natural flow regime of large rivers and organisms have adaptations for utilizing these habitats when they are seasonally available (Poff et al. 1997). Oxbow and off-channel habitats are significant locations for maintaining fish diversity in medium and large river ecosystems (Winemiller et al. 2000).

Floodplain lakes in the Patoka River National Wildlife Refuge (NWR) were isolated with a historical dredging project. This project has a longterm goal of restoring a natural flooding regime to these floodplain lakes by removing levees in the refuge. The current project provides background data for fish assemblages prior to modifications.

The stream fishes of Indiana provide the state many positive returns including benefits to anglers, for ecosystem services, and as a portion of a natural heritage. Although there are several local extinctions, the majority of fish species that were here historically are still present. In addition the current fish assemblages of Indiana have higher occurrences of species that are tolerant to human disturbances (Jacquemin & Pyron 2011). Protection of existing fish species in floodplains requires restoration of habitats through reconnection to mainstem rivers.

Research Objectives: The project is a combination of field collections with habitat data.

Methodology: We sampled ten floodplain lakes in the Patoka River NWR (Figure 1). Lakes were selected based on proximity to the Houchin Ditch and mainstem Patoka River, with a goal to sample lakes with the potential to be reconnected to the river during flood periods. Fish sampling was by backpack or barge

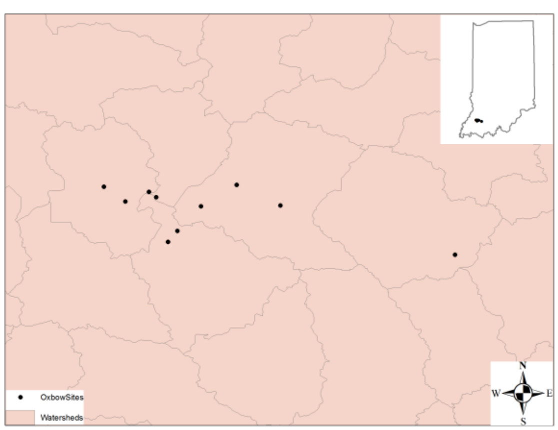

Figure 1. Site locations for floodplain lakes in the Patoka River National Wildlife Refuge.

electrofisher with two persons to net fishes. We collected in all available habitats or for 30 min per site. Fishes were identified and released at the site. The habitat data were maximum depth, substrate composition, and distance to the river.

Results: Collections resulted in 257 individuals in 22 species (Table 1). Mean species richness at sites was 5 and ranged from 1-11. Mean site abundance was 23.4 individuals, and ranged from 1 – 74. Mean maximum depth was 1.1 m, with a range from 0.5 – 2 m. Mean distance from the river mainstem was 1.9 km, with a range from 1.2 – 2.4 km.

A Principal Components (PC) analysis resulted in three axes that explained 36.5, 16.4, and 12.1 % of total variation. The first PC axis was explained by increased abundances of Green Sunfish, Black Crappie, and Warmouth (Figure 2). This axis was not significantly correlated with habitat variables. The second PC axis was explained positively by Flier and Bowfin, and negatively by Bluegill (Figure 3). This axis was positively correlated with distance to the river (r = 0.6, P = 0.05). The third PC axis was explained positively by Longear Sunfish and River Carpsucker, and negatively by Shorthead Gar and Redear Sunfish (Figure 3). This axis was positively correlated with maximum depth (r = 0.64, P = 0.03). Sites that were further from the river tended to contain increased abundances of Bowfin and Flier, and lower abundances of Bluegill. Sites with increased depth tended to have increased abundances of Longear Sunfish and River Carpsucker, and decreased abundances of Shortnose Gar and Redear Sunfish.

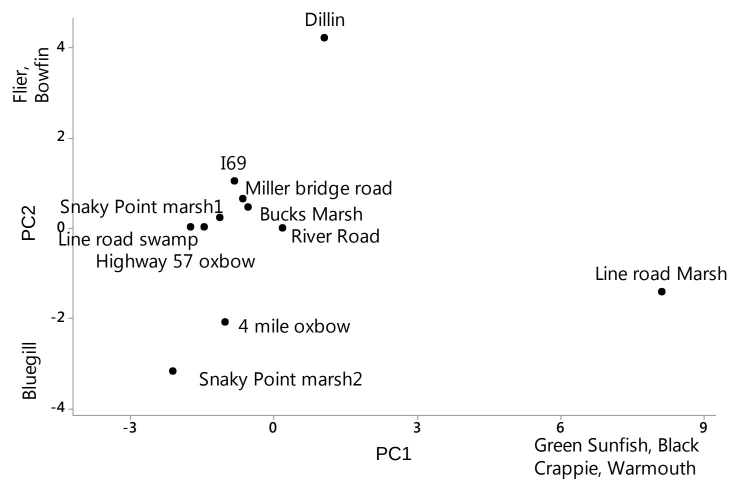

Figure 2. First two axes of a Principal Component Analysis of fish abundances for 11 Patoka River NWR sites.

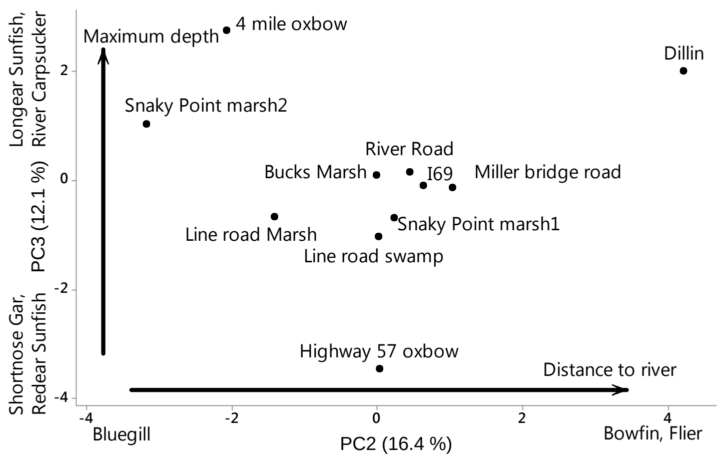

Figure 3. Second and third axes from a Principal Components Analysis of fish abundances for 11 Patoka River NWR sites.

Major Conclusions and Significance: Dominant species in the Patoka River NWR were Bluegill and Western Mosquitofish. These were also the highest abundance species in 2007 collections by Simon et al. (2015) and are tolerant to disturbance and/or human impacts. Collections did not results in taxa not present in 2006-7 by Simon et al. (2015). The collections in 2006-7 resulted in fishes sensitive to siltation and acidity that were previously unknown to the Patoka River NWR (Lake Chubsucker, Paddlefish, Rock Bass, Slough Darter, Harlequin Darter, Blackside Darter, Dusky Darter, and Banded Sculpin. These species have the potential to occur in floodplain lakes with increased flood duration and frequency. We will resample these sites in 2015, to increase sample size and include annual variation in fish assemblage structure.

Publications: Poster presentations at conferences:

Minder, M. and M. Pyron. Off-channel habitats of the Patoka River, Indiana. Society for Freshwater Science, Milwaukee, WI, May 2015.

Minder, M., M. Pyron and L. Etchison. Off-channel habitats of the Patoka River, Indiana. Midwest Fish & Wildlife Conference, Indianapolis, IN, Feb 2015.

Grant Submissions:

Letter of Intent to Pursue Restoration of Patoka River NWR floodplain lakes, US Army Corps of Engineers Louisville Office, $60,000.

2015 Aquatic Nuisance Species: Effects of Silver Carp on Food Webs of the Wabash River Ecosystem, USFWS, Apr 2015, $30,000.

Students: One graduate student supported on project, two additional graduate students participated

References:

Galat, D.L., L.H. Fredrickson, D.D. Humburg, K.J. Bataille, J. Russell Bodie, J. Dohrenwend, G.T. Gelwicks, J.E. Havel, D.L. Helmers, J.B. Hooker, J.R. Jones, M.F. Knowlton, J. Kubisiak, J. Mazourek, A.C. McColpin, R.B. Renken and R.D.

Semlitsch. 1998. Flooding to restore connectivity of regulated large-river wetlands. Bioscience 48:721-733.
Jacquemin, S.J. and M. Pyron. 2011. Fishes of Indiana streams: current and historic assemblage structure. Hydrobiologia 665:39-50.
Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestegaard, B.D. Richter, R.E. Sparks and J.C. Stromberg. 1997. The natural flow regime. Bioscience 47:769-784.
Simon, T.P., C.C. Morris, J.R. Robb, and W. McCoy. 2015. Biological diversity, ecological health and condition of aquatic assemblages at National Wildlife Refuges in Southern Indiana, USA. Biodiversity Data Journal 3:e4300.
Winemiller, K.O., S. Tarim, D. Shorman and J.B. Cotner. 2000. Fish assemblage structure in relation to environmental variation among Brazos River oxbow lakes. Transactions of the American Fisheries Society 129:451-468.

Table 1. Fish abundances by site, in Patoka River National Wildlife Refuge. Collections were 9/3/2014.

Site name	Green Sunfish	Golden Shiner	Central Mudminnow	Warmouth	Black Crappie	Redfin Shiner	Starhead Topminnow	Brown Bullhead	Pirate Perch	Redfin Pickerel
Bucks Marsh										2
Snaky Point marsh										
Line road Marsh	14	15	2	1	1	1		13	1	6
Miller bridge road							4		1	
River Road		1	1						1	
Dillin		1							1	4
4 mile oxbow		1								1
Highway 57 oxbow										
Line road swamp										
Snaky Point marsh							1			
I69										1

Gizzard Shad										2	
Bowfin						2					
Spotted Gar										1	
Blackstripe topminnow	2	0			4		2	1	1	1	
Western Mosquitofish	8		18	3	7	30	2				
Bluegill	1	1	2	1	2		26	1	1	49	1
Redear Sunfish								1			
Common Carp									1		
Flier						7					2
Shortnose Gar								1			
River Carpsucker							1				
Longear Sunfish							1				
Site	Bucks Marsh	Snaky Point marsh	Line road Marsh	Miller bridge road	River Road	Dillin	4 mile oxbow	Highway 57 oxbow	Line road swamp	Snaky Point marsh	I69

A History of Metal Pollution in the Wabash River, Vigo County, Using Geochemical Records from Pond and Wetland Sediments

Basic Information

Title:	A History of Metal Pollution in the Wabash River, Vigo County, Using Geochemical Records from Pond and Wetland Sediments
Project Number:	2014IN371B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	04
Research Category:	Not Applicable
Focus Category:	Geochemical Processes, Nutrients, Sediments
Descriptors:	None
Principal Investigators:	Jennifer C Latimer

Publications

There are no publications.

General Report Format

Report Format

Cover Page---

Project Id:

Title: A History of Metal Pollution in the Wabash River, Vigo County, Using Geochemical Records from Pond and Wetland Sediments

Project Type: Research

Start Date: 3/01/2014 **End Date:** 2/28/2016

Congressional District: 8th

Focus Categories: Geochemical Processes, Nutrients, Sediments, Water Quality, Wetlands

Keywords: Biogeochemistry, Pollution, Metals, Nutrients

Principal Investigators: Jennifer C. Latimer

Abstract / Summary:

The Wabash River is an iconic feature in the state of Indiana, but it is plagued by the perception of poor water quality. In Vigo County, the wetlands along the Wabash River have drawn a lot of new attention in recent years as a habitat for wildlife and area for recreation through initiatives such as Riverscape and the Year of the River, which have served to increase awareness about the Wabash River as a community resource. The research proposed here will evaluate heavy metals and nutrients (phosphorus) in sediment cores recovered from ponds and wetlands adjacent to the river that are intermittently connected when the river floods and act as sediment traps. Preliminary results from a pond (International Paper (IP) holding pond) located in Terre Haute's old industrial park illustrate a trend of decreasing heavy metals over time. Despite this trend, metal concentrations throughout the core are greater than typical background values. The sediment core from the IP holding pond will be further evaluated for metals and nutrients (phosphorus), and new cores will be collected from the Wabashiki Fish and Wildlife Area (WFWA) for similar analyses. It is anticipated that the cores will demonstrate that the intensity of metal pollution has decreased over time, while nutrient loading has increased. The data generated here will be shared with Terre Haute's City Planner, Pat Martin, and DNR (Mark Huter) as well as other interested community groups. The results will be the basis for at least two undergraduate research projects, and will be incorporated into the curriculum for the introductory environmental science course (ENVI110L).

Problem:

The Wabash River is notorious for poor water quality, despite the fact that water quality has improved significantly over the past several decades. Sediments within the river are course grained sands, and are not conducive for sampling for geochemical analysis. Instead, the purpose of the project proposed here is to look at heavy metals and phosphorus in sediments collected adjacent to the river in ponds and wetland sediments. These adjacent environments act as sediment traps for fine-grained materials and organic matter when the Wabash River floods, especially during the spring. It is hypothesized that these sediment cores will reflect a history of urban pollution within the Wabash River and will demonstrate that the intensity of pollution has decreased over time.

Research Objectives:

The objective of this project is to identify the extent and temporal records of metal pollution and nutrient loading in depositional environments adjacent to the Wabash River within Vigo County. It is hypothesized that metal loading has decreased to these sediment traps while nutrient loading has increased over time. Because of legislation like the Clean Water Act, the point sources of pollution to water bodies has generally decreased, which would lead to fewer metals in surface waters. However, nutrient pollution from urban areas (i.e. fertilizer on yards and golf courses) and agricultural areas continues to increase and impair water quality. For these reasons, it is expected that an overall trend of decreasing metal concentrations over time will be seen. It is also expected that an opposite trend will be seen in phosphorus geochemistry (nutrients) with higher values near the surface of the cores.

Methodology:

Additional geochemical analysis of the IP holding pond sediment core will be completed as well as geochemical analysis of the cores collected at the WFWA. Two short cores have been collected from WFWA. A longer core will be collected in June 2015. All samples have been dried and powdered. The samples were ashed to determine organic matter content via loss on ignition and extracted using 2M nitric acid following EPA SW-846 Method 3050B (Souch et al., 2002). Samples were shaken on an orbital shaker at room temperature for 16 hours then analyzed via inductively coupled plasma-optical emission spectroscopy (ICP-OES) for a suite of elements that includes the EPA priority pollutants (arsenic, lead, copper, chromium, cadmium, and zinc). Samples have also been subjected to a sequential extraction technique for phosphorus (Ruttenberg, 1992) to evaluate phosphorus loading and retention in the sediments. The extraction technique differentiates phosphorus that is adsorbed to particle surfaces, phosphorus associated with oxides and oxyhydroxides, phosphorus associated with organic matter, and mineral phosphorus that is not available to biota. All sample processing and analyses has taken place in the Biogeochemistry Laboratory managed by J. Latimer at ISU. The results of this work will provide a history of metal pollution and nutrient loading to the study sites.

Results:

All data has been collected for the IP and short cores from WFWA; however, not all of the data has been analyzed. The analyses are currently under way. Initial results suggest that WFWA has not experienced the same level of heavy metal pollution as IP, at least based on the core samples we have collected to date.

Major Conclusions and Significance

We have yet to analyze all of the samples for nutrient (phosphorus) concentrations to evaluate nutrient loading. However, WFWA, which is an important wetland habitat in an urban setting does not appear to have been significantly impacted by heavy metal pollution, compared to IP.

Publications

Abstracts

Latimer, J.C., McLennan, D., Stone, J.R., Memmers, E., Foster, J., Hardin, K.J., Nickerson, Z., Portwood, C.A., Williams, T., Short sediment cores as archives of urban pollution, American Geophysical Union Fall Meeting, San Francisco.

Latimer, J.C., Hardin, K., Portwood, C., Nickerson, Z., Stone, J., 2014. Urban Sediment Cores as an Archive of Historical Pollution, 2014 Urban Health Conference: New Dimensions in Urban Health and Action, Indianapolis.

Hardin, K., Portwood, C., Latimer, J.C., 2014. Geochemical analysis and diatom assemblages of International Paper Holding Pond in Terre Haute, Indiana, National Conference on Undergraduate Research, Lexington, KY.

Grant Submissions: N/A

Students

Undergraduate Students: 8

Graduate Students: 1

Linking improved soil health to water quality via the planting of cover crops in the Shatto Ditch Watershed, Kosciusko Co, IN.

Basic Information

Title:	Linking improved soil health to water quality via the planting of cover crops in the Shatto Ditch Watershed, Kosciusko Co, IN.
Project Number:	2014IN372B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	01
Research Category:	Water Quality
Focus Category:	Nitrate Contamination, Non Point Pollution, Nutrients
Descriptors:	None
Principal Investigators:	Jennifer L Tank, Sheila F Christopher

Publications

There are no publications.

Title: Linking improved soil health to water quality via the planting of cover crops in the Shatto Ditch Watershed, Kosciusko Co, IN.

Project Type: Research

Start Date: 3/01/2014 **End Date:** 2/28/2015

Congressional District:

1st District (University of Notre Dame)
2nd District (Study Area in Kosciusko County)

Focus Categories:

NC, NPP, NU, SW, WQL

Keywords:

Cover crops, Nitrogen, Nitrate, Ammonium, Phosphorus, Tile drain, Water quality

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Abstract / Summary

In the Midwestern US, tile drainage is a necessary management tool supporting agricultural production in modern farming systems. However, this practice facilitates the delivery of excess nutrients to downstream water bodies. These non-point sources contribute to elevated nutrients in Lake Erie and the Gulf of Mexico, which have been linked to algal blooms and subsequent widespread hypoxia causing widespread ecological and economic problems. To mitigate these negative effects, we need a mechanistic understanding of controls on water quality in agricultural watersheds. Although previous research has examined how individual management practices affect nutrient leaching from individual fields *or* small stream reaches, less is known about the *linkages* between terrestrial and aquatic systems that influence water quality at a watershed scale. Planting winter cover crops (CC) after fall harvest offers a potential mechanism to reduce nutrient leaching from agricultural fields dominated by row-crop agriculture. We used a demonstration project in the Shatto Ditch Watershed (SDW), located in the Tippecanoe River Basin in Kosciusko County, IN to quantify how cover crops planted over 1800 acres (~75%) of this small agricultural watershed in Fall 2013 influenced the linkage between landscape practices and water quality. The specific objectives of our study were to quantify the effect of cover crops on soil nutrient concentrations, N cycling, and soil microbial community function. We also wanted to determine if there were predictable relationships between soil nutrient content and tile drain nutrient leaching. During Fall 2013, Spring 2014, and Fall 2014, we sampled soil and tile drains from fields with and without cover crops in the SDW. In Spring 2014, soil NO_3^--N concentration was significantly lower in fields planted in CC (2.3+/-0.36 mg NO_3^--N kg^{-1}) versus non-CC treatments (5.7+/-0.65 mg NO_3^--N kg^{-1}). Post CC termination, in Spring 2014, we also found an increase in nitrification rates in fields with cover crops (0.42+/- 0.06 mg N ha^{-1} d^{-1}) versus those fields without CC (0.28 +/- 0.01 mg N ha^{-1} d^{-1}) suggesting cover crop residue was nitrified and N was available for future cash crop growth. We did not observe a significant increase in SOC in fields with CC versus those without CC in any season yet preliminary bioplate data suggested that microbial community health and function improves in fields that contain CC, suggesting organic matter quality was improving with CC. Finally, we found a positive relationship between deep soil and tile drain NO_3^--N (r^2=0.94, p = 0.0001) suggesting that cover crops could reduce NO_3^--N loss from tile drains. Given these results, seasonal, year-round study of soil and tile drain chemistry is warranted to determine soil and water quality benefits of cover crops.

Problem and Research Objectives

Over the past 150 years, much of Indiana has undergone extensive land use changes as vast wetlands and prairies have been converted to productive cropland. However, the tile drainage systems that keep soils dry and maintain productive agriculture also significantly impact adjacent stream channels. Excess fertilizer nutrients like nitrogen (N) and phosphorus (P) enter streams via tile drain[1] and are then exported downriver causing numerous environmental problems including contaminated drinking water, loss of biodiversity, downstream algal blooms, and subsequent hypoxic “dead zones” after those blooms die and decompose. For example, >50% of the N and P causing periodic hypoxia in the Gulf of Mexico has been linked to fertilizers applied to row-crop agriculture centered in the Midwestern US[2]. We need a mechanistic understanding of nutrient transport in agricultural watersheds in order to maintain productive agriculture while simultaneously conserving freshwater resources in the Midwestern US.

The planting of cover crops as a landscape level BMP is gaining popularity; previous field scale research has shown that they can reduce nutrient and sediment export from agricultural fields while maintaining soil health. Historically, cover crops have been planted after cash crop harvest to reduce soil erosion, decrease soil compaction, increase soil organic matter, and suppress weed growth[3]. Increased uptake (i.e., immobilization) by cover crops of residual soil N during the winter and spring, when fields are normally bare[4], also significantly reduces nutrient concentrations in the soil leaving fewer nutrients available for leaching to streams[5]. Microbial diversity of soils and resultant nutrient cycling have also been shown to be influenced by management practices such as cover crop planting[6,7]. Increased nutrient release of cover crop residue via microbial decomposition (i.e., mineralization) during summer[8] provides a sustained nutrient source for the growing cash crop.

Previous research has examined how BMPs influence nutrient leaching from individual fields *or* short stream reaches, but less is known about *linkages* between terrestrial and aquatic systems that are reflected in water quality at the watershed scale. Most studies have focused on BMP implementation in one component of the watershed (e.g., soil or stream) and we lack an understanding of how complex interactions among terrestrial and aquatic ecosystems influence watershed nutrient export[9]. Few studies have examined nutrient transformations and leaching from soils to tile drains to streams that link the implementation of landscape BMPs such as cover crops with stream water quality at the watershed scale.

Our pre-treatment year of data collection (pre-cover crop planting) on our USDA-CIG grant and our regular (every 10 days) tile drain sampling confirms that the highest concentrations of nitrate (NO_3^-) and soluble reactive phosphorus (SRP) in tile flow are entering streams during winter and spring when fields are fallow. The cover crop growing season coincides with these critical times for nutrient loss from fields; therefore, cover crops have the potential to significantly reduce nutrient export via tile drain outlets. Using support from our 2013 IWRRC grant, we examined the impact of cover crop planting on soil nutrient content and tile drain leaching during Summer and Fall 2013 and found promising inverse relationships between soil NO_3^- and N loss in tile drains; however, the 2013 IWRRC budget limited our seasonal sampling and the conclusions we can make about watershed-scale implementation of cover crops during critical times of nutrient export. For this proposal, we built on previous research in Shatto Ditch Watershed (SDW) to determine the effects of watershed-scale cover crops on soil nutrient content, nutrient leaching to tile drains, and resultant year-round water quality including Winter and Spring during times of high nutrient export. We also added a new metric to quantify soil microbial community function (i.e., using BIOLOG EcoPlates™), which increased our understanding of soil nutrient dynamics during critical times of N and P export. The specific objectives of our project and associated hypotheses were as follows:

Objective 1) Determine if cover crops increase soil nutrient and organic matter content after cover crop planting (Fall 2013, Spring 2014 and Fall 2014), compared to fields without cover crops.

Objective 2) Determine if cover crop planting increases seasonal soil N mineralization rates via increased decomposition of cover crop residue compared to fields without cover crops.

Objective 3) Determine if increased root biomass and exudates during cover crop growth in early Spring, combined with higher nutrient availability after cover crop termination in mid- Spring, will improve soil microbial community function compared to fields without cover crops.

Objective 4) Determine if there is a year-round predictable relationship between soil nutrient content and tile drain leaching where higher soil nutrient content is correlated with lower nutrient export through tile drain leaching.

Methodology

Building on our USDA-CIG and 2013 IWRRC grants, as well as our strong partnership with the Kosciusko County SWCD and NRCS, we began with a six-year monitoring record of stream water quality at SDW (Figure 1) that reflects the "watershed condition" prior to the planting of cover crops, and starting in September 2013 have added watershed-scale (~75% coverage) planting of cover crops. With this strong experimental approach, we quantified the influence of cover crops on soil and water nutrient dynamics at watershed scale.

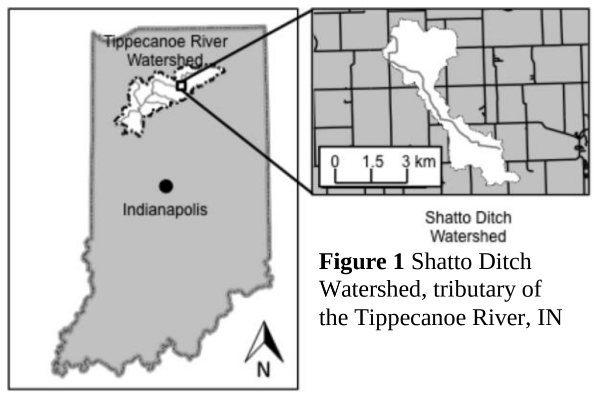

Figure 1 Shatto Ditch Watershed, tributary of the Tippecanoe River, IN

For Objective 1, we quantified soil nutrients and organic matter content. As part of our 2013 IWRRC grant, we identified 12-15 field plots with 9 containing tile drains that served as the plot centerline. We grouped these field plots into 3 different management practices including 1) previously cover-cropped 1 year prior to our study (here after called "Long-term cover crop" plots), 2) planted in cover crop Fall 2013, and 3) never cover cropped (a control). We sampled soil in these same fields during 1) cover-crop planting season (Fall 2013), 2) pre and post cover crop termination (Spring 2014), and 3) cover-crop planting season (Fall 2014). Within each field, we established three transects, that were perpendicular to the tile drain, as well as 3 transects directly above the tile drain. We collected soil at 0-5 cm and 5-20 cm depths at 6 points along the transects and we homogenized 2 samples per transect from each depth and each field for a total of 12 samples per field. Soil samples were transported on ice to the Tank Laboratory at Notre Dame for further chemical analysis. Soil moisture content was determined gravimetrically by oven drying at 105 °C for 24h. Total C (TC) was determined using the dry combustion method (900 °C) with a Costech Elemental Analyzer. Soil pH was used to determine the presence of inorganic C; pH values < 7.6 indicated TC could be assumed to be soil organic carbon (SOC). Nitrate (NO_3^--N) and ammonium (NH_4^+-N) were extracted using 2 M KCl while water extractable P (WEP) was extracted with ultra-pure water, all analyzed using colorimetry on a Lachat QC-8500 flow injection auto-analyzer. Total dissolved N (TDN) was determined after KCl extracts were digested using persulfate on the Lachet auto-analyzer. Total P (TP) was determined after acid digestion and Mehlich III P extractions were performed at Brookside Laboratories, OH. We performed a randomized split-plot analysis of variance by season to test the hypothesis that differences in N and P species occurred due to differences between land use (cover crop type, no cover crop) and/or soil depth (0-5 cm, 5-20 cm).

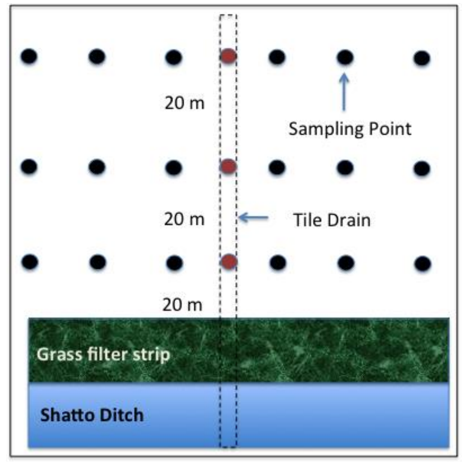

Figure 2 Sampling scheme for one field near a tile drain. Black dots indicate a sampling location at two depths

For Objective 2, we quantified net nitrification (NO_3^--N production) and mineralization (NO_3^--N + NH_4^+-N production) rates using an *in situ* buried bag experiment at three points in each field at the 0-5 cm depth during Spring and Fall 2014. We placed ~100 g of soil in polyethylene bags and then bury them at 0-5 cm to incubate for 28d. We calculated net mineralization rates by subtracting initial soil NO_3^--N + NH_4^+-N content from incubated NO_3^--N + NH_4^+-N content. We calculated net nitrification rates by subtracting initial soil NO_3^--N content from incubated soil NO_3^--N content. For statistical analysis, we performed a randomized split-plot analysis of variance (ANOVA) with repeated measures to test the hypothesis that differences in N species as well as N production occur due to differences between land use (cover crop type, no cover crop) and/or soil depth (0-5 cm, 5-20 cm).

For Objective 3, we used intensified Spring soil sampling to examine the effects of cover crops on microbial community function using BIOLOG EcoPlates™ which assay carbon-source utilization patterns to determine potential microbial community function and diversity. Using a subset of fields, we bulked a sub-set of all samples from six field plots to obtain one representative sample per field during Spring 2014 soil sampling bracketed pre and post cover crop termination. We will perform a randomized ANOVA to test the hypothesis that differences in microbial diversity and function are due to differences between treatments (pre and post-cover crop termination).

For Objective 4, every 10 days, we collected water samples for water chemistry analysis, from the major tile drains associated with each soil sampling site using funds from the USDA-CIG grant. For each sample we quantified concentrations of NO_3^--N, NH_4^+-N, and SRP. For Fall 2014 only, we sampled soil at 20 to 40 cm and 40 to 50 cm and analyzed N and P constituents as described under Objective 1 because we hypothesized that deep soil may correlate stronger with tile flux than shallow soil. We tested the hypothesis that differences in tile drain fluxes are related to differences in soil nutrient content using least-squares linear regression.

Results

Objective 1: First, we measured N, P, and C species in the soil to determine the effect of cover crops on soil nutrient and SOC. We predicted that the planting of cover crops would decrease extractable soil N and P and increase SOC content. In Spring 2014, NO_3^--N was significantly lower in fields with cover crops versus fields without cover crop (Figure 3) ($p = 0.019$). This trend suggests that N possibly was retained in cover crop tissue during spring. We did not find significantly differences in P species or SOC among the management practices in fall or spring (data not shown). We predict that it would take several years for organic material to build

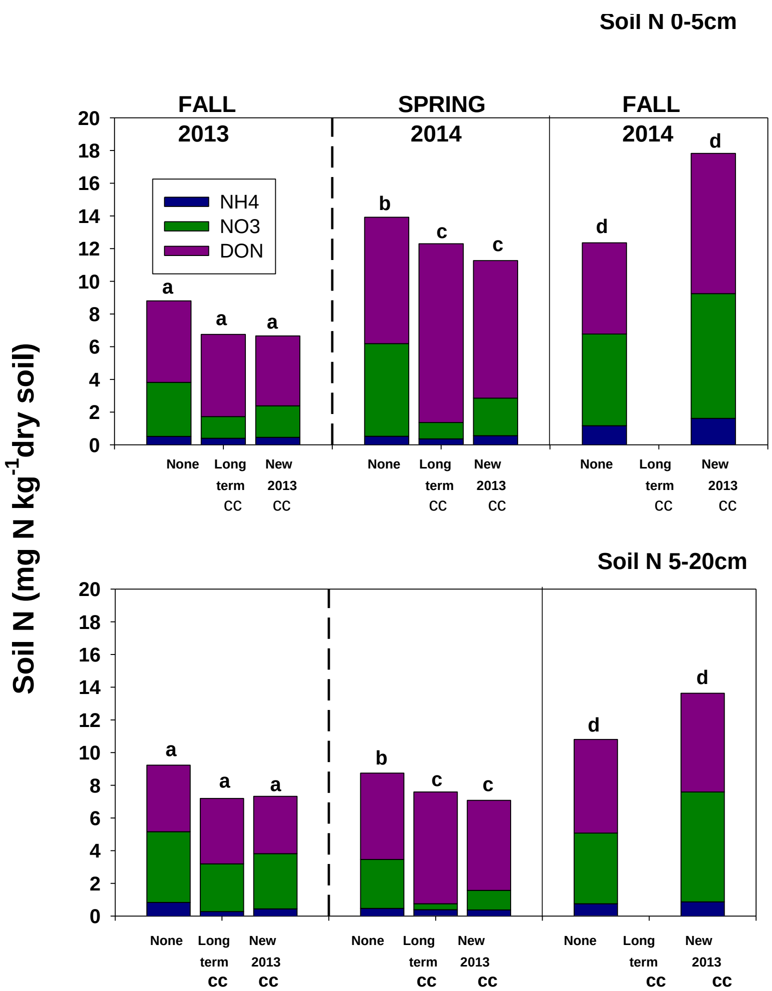

Figure 3 DON, NO_3^--N, NH_4^+-N concentration in fall 2013, Spring 2014, and Fall 2014 in 0-5 cm (top) and 5-20 cm (bottom) soil. Letters that differ within each depth and season indicate differences in NO_3^--N among management practices at the 0.05 level.

in fields with cover crops and likewise several years to detect differences in SOC among management practices.

<u>Objective 2:</u> We assessed whether cover crop planting increases seasonal soil N cycling. Preliminary results from our incubation study suggests that both net N nitrification and mineralization are higher in fields with cover crops versus those fields without cover crops suggesting cover crop residue could have been nitrified and N could have been available for future cash crop growth (Figure 4).

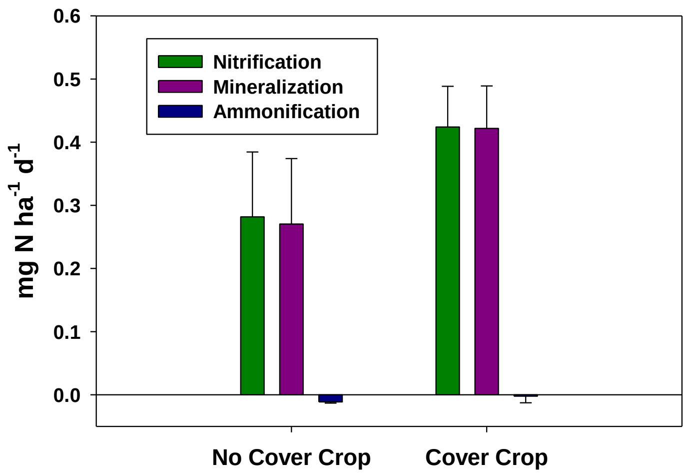

Figure 4 Mean Spring 2014 net nitrification, mineralization, and ammonification rates in fields with and without cover crops

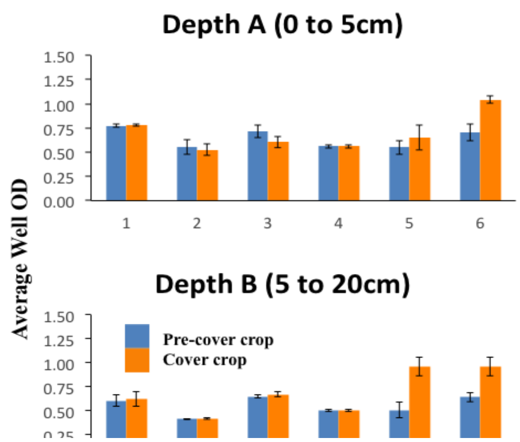

Figure 5 Mean Spring 2014 well optical density in fields pre and post cover crop termination.

<u>Objective 3:</u> We assessed whether cover crop planting will improve soil microbial community function compared to fields without cover crops. Preliminary results indicated that optical color density and therefore respiration in several fields increased in fields with cover crops, which suggests that microbial community health and function improves in fields with cover crop compared to fields without cover crops (Figure 5).

<u>Objective 4:</u> We sampled tile drains from field plots during Fall 2014. We determined that there was a significant positive relationship between deep soil NO_3^- - N concentration and tile drain NO_3^--N flux (Figure 6) suggesting that cover crops could reduce NO_3^- - N loss from agricultural fields.

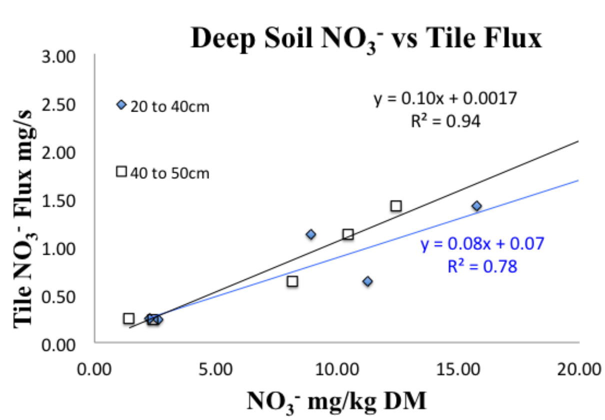

Figure 6 Relationship between NO_3^--N concentration in deep soil and NO_3^- - N flux in tile drains

Major Conclusions and Significance

Cover crop fields had significantly lower NO_3^--N concentration than fields without cover crops in Spring 2014. We did not observe a significant increase in SOC or decrease P in fields with cover crop versus those without cover crop yet preliminary bioplate data suggested an increase in microbial function in fields with cover crops likely due to an increase in organic matter quality, which could occur prior to a noticeable change in organic matter quantity. We expect SOC will increase over time and we will continue to monitor SOC in subsequent years of our long-term study. Finally, there was also a positive relationship between NO_3^--N concentration and tile drain NO_3^--N flux suggesting that cover crops could help retain N and prevent N leaching from agricultural fields.

Further evaluation of soil and tile drain chemistry during all seasons is warranted to understand the linkage between soil health and tile and stream chemistry. As we finish our project associated with funding from Indiana Water Resources Research Center, we have sampled soil and tile drains post cover crop termination in Spring 2015, and we will sample post cover crop termination in Summer 2015. We hope to further understand and quantify how the planting of cover crops influence soil nutrient content and tile drain nutrient leaching. A mechanistic understanding of how land management impacts stream water quality in agricultural watersheds throughout the year will be essential in order to balance the needs for successful agriculture and conservation of freshwater resources in the Midwestern US, including those in Indiana.

Publications

Presentations:

Tank, J.L., Hanrahan, B.R., Dee, M., Christopher, S.F. 2014. Management Strategies to Reduce Nutrient Pollution from Agricultural Land Use to Improve Water Quality. Reports to USDA-NRCS Indiana, March 21, 2014 and April 11,2014, Indianapolis, IN.

Christopher, S.F., Tank, J.L., Hanrahan, B.R., Mahl, U.H. 2014. Linking Soil Health to Improved Water Quality Via the Planting of Cover Crops in the Shatto Ditch Watershed, Kosciusko Co, in. Soil and Water Conservation Society 2014 Annual Conference, July 27-30, 2014, Lombard, IL.

Tank J.T., Christopher S.F., Hanrahan, B.R. 2014 Linking cover crops to improved stream water quality via field-scale soil sampling, in Shatto Ditch Watershed, IN, Conservation Innovation Grant Proposal Meeting August 14, 2014.

Tank, J.T. 2014. Pairing in-stream and landscape conservation to reduce stream water nutrients exported from agricultural watersheds, Joseph W. Jones Ecological Research Center, Newton GA, September 2014.

Tank, J.T. 2014. Freshwater Conservation at the Land-Water Interface: What is working? The Nature Conservancy Global Water Summit, Chicago IL, November 2014.

Christopher, S.F., Tank, J.L., Hanrahan, B.R., Mahl, U.H. 2014. Linking Soil Health to Improved Water Quality Via the Planting of Cover Crops in the Shatto Ditch Watershed, Kosciusko Co, in. American Society of Agronomy, Crop Science Society of America , and Soil Science Society of America 2014 Annual Conference, November 2-5 2014, Long Beach, CA.

Tank, J.T. 2014. Monitoring the effect of watershed-scale pairing of cover crops and the two-stage ditch on water quality. Indiana Agriculture and Water Monitoring Council Symposium. December 2014.

Grant Submissions

1. NSF Science and Technology Center, Pre-proposal: Center for Engagement in Watershed Solutions, The Ohio State University, (6/2016-5/2021), PI: Weavers, L., CoPI: Lemmon, M. et al., UND Center Participants: Berke, M., Bolster, D., Christopher, S.F. Gupta, V., Steiner, A. Tank. J.L., et al. *$4,000,000, Selected to submit Not-funded.*

2. NSF Science and Technology Center, Pre-proposal: Consortium for Freshwater Science and Technology, Michigan State University, (6/2016-5/2021), PI: Weavers, L., CoPI: Lamberti, G. et al., UND Center Participants: Berke, M., Bolster, D., Christopher, S.F. Gormley, M., Gura, Gupta, V., Hamlet, H., Hellmann, J., Jones, S., Lemmon, M., Lodge, D., Sharma, A., Steiner, A. Tank. J.L., Westerink, J., et al., *$4,000,000, Not-funded.*

3. U.S. Department of Agriculture (USDA) Regional Conservation Partnership Program (RCPP): Preventing nutrient loss from Indiana farms: watershed-scale pairing of cover crops and the two-stage ditch, (1/2015-12/2019), PI: Tank, J.L., CoPIs: Christopher, S.F. Royer, T.V. *$2,247,003, Awarded.*

4. Indiana Soybean Alliance: Watershed scale adoption of cover crops and the two-stage ditch in Indiana: responses in water quantity and quality, (5/2015-4/2016), PI: Tank, J.L., CoPIs: Christopher, S.F., Royer, T.V., $114,259 (with match), *Awarded.*

5. US Geological Survey: Water quality and quantity responses from the watershed-scale pairing of cover crops and the two-stage ditch, (9/2015-8/2018), PI: Tank, J.L., CoPIs: Christopher, S.F., Royer, T.V., $530,462 (with match), *Pending.*

6. National Science Foundation Preliminary Proposal: Quantifying responses in hydrology and watershed biogeochemistry to land cover and climate change in an agricultural landscape. PI: Tank, J.L., CoPIs: Christopher, S.F., Royer, T.V., Hamlet, A.F., Sharma, A. *Pending.*

7. National Fish and Wildlife Foundation Pre-proposal: Quantifying water quality responses from the watershed-scale pairing of cover crops and the two-stage ditch (6/1/2015-5/31/2017), PI: Tank, J.L., CoPIs: Christopher, S.F. Royer, T.V. $333,635 (with match), *Pending.*

Students

With the IWRRC funds, 2 undergraduate researchers, Karen Huang and Kevin Fick (funded via Notre Dame cost-share), helped with field sampling and lab analyses. Karen and two other students (Thomas Davis and Caleb Bomske) completed independent research projects associated with the IWRRC project for which they were able to gain academic credits. Brittany Hanrahan, a 3rd year PhD student, is already funded through the USDA-CIG project, and took the lead on all tile drain sampling and bioplate analysis. Results from this project will contribute to her dissertation. All students learned critical skills on design, data collection, and information dissemination, which will be instrumental for their future careers.

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[1] Cooper CM. 1993. Biological effects of agriculturally derived surface water pollutants on aquatic systems-A review. J. Environ. Qual. 22: 402-408.

[2] Alexander RB, Smith RA, Schwarz GE, Boyer EW, Notal JV, Brakebill JW. 2008. Differences in phosphorus and nitrogen delivery to the Gulf of Mexico from the Mississippi River Basin. Environ. Sci. and Technol.42: 822-830.

[3] Lal R, Regnier E, Eckert DJ, Edwards WM, Hammond R. 1991. Expectations of cover crops for sustainable agriculture. pp.1–11. *In* WL Hargrove (ed.) Cover crops for clean water. Proc. Int. Conf., Jackson, TN. 9–11 Apr. 1991. Soil and Water Conserv. Soc. Am., Ankeny, IA.

[4] Ranells NN and Wagger MG. 1997. Nitrogen-15 recovery and release by rye and crimson clover cover crops. Soil Sci Soc. Am. J. 61: 943-948.

[5] Kaspar TC, Jaynes DB, Parkin TB, Moorman TB. 2007. Rye cover crop and gamagrass strip effects on NO3 concentration and load in tile drainage. Journal of Environmental Quality 36: 1503-1511

[6] Bucher, A.E., Lanyon, L.E. 2005. Evaluating soil management with microbial community-level physiological profiles. Applied Soil Ecology 29: 59-71.

[7] Wagger MG, Cabrera ML, Ranells NN. 1998. Nitrogen and carbon cycling in relation to cover crop residue quality. J. Soil Water Cons. 53(3) 214-218.

[8] Quemada M, Cabrera ML. 1995. Carbon and nitrogen mineralized from leaves and stems of four cover crops. Soil Sci. Soc. Am. J. 59: 471-477.

[9] Sharpley AN, Kleniman PJA, Jordan P, Bergstrom L, Allen AL. 2009. Evaluating the success of phosphorus management from field to watershed. J.Environ.Qual. 38: 1981-1988.

Evaluating the Maintenance and Diffusion of Best Management Practices in the Great Bend of the Wabash River Watershed

Basic Information

Title:	Evaluating the Maintenance and Diffusion of Best Management Practices in the Great Bend of the Wabash River Watershed
Project Number:	2014IN375B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	04
Research Category:	Social Sciences
Focus Category:	Conservation, Education, Law, Institutions, and Policy
Descriptors:	None
Principal Investigators:	Linda Prokopy

Publications

There are no publications.

Project Id:

Title: Evaluating the Maintenance and Diffusion of Best Management Practices in the Great Bend of the Wabash River Watershed

Project Type: Research

Start Date: 3/01/2014 **End Date:** 2/28/2015

Congressional District: Indiana District 4

Focus Categories: COV, EDU, LIP, M&P, NPP, WQL, WQN, WS, WU

Keywords: best management practices; climate change; non-point source pollution; watershed-based planning

Principal Investigators: Prokopy, Linda S., Associate Professor, Purdue University, Forestry and Natural Resources, Forestry Building, Room 201, 195 Marsteller Street, West Lafayette, Indiana, 47907, lprokopy@purdue.edu, (765) 496-2221

Abstract

This project characterizes the *adoption, maintenance* and *diffusion* of water quality and climate change BMPs in the Region of the Great Bend of the Wabash River Watershed. In late 2014, Natural Resources and Social Science Lab in Purdue University conducted a social indicator survey in Great Bend of the Wabash Watershed, targeting for rain barrel adopters. The survey asked respondents about their perceptions about local water quality, their constraints in adoption and maintenance of rain barrels, their awareness of various best management practices, and themselves in terms of background and demographics. To understand what motivates the adoption and maintenance of these BMPs in this watershed, an assessment of both the *property owner/manager* and the *actual practice* were conducted. The survey and the assessment results aimed to determine specific watershed management planning recommendations for setting adoption goals and reaching potential adopters for the environmental non-profit organization, Wabash River Enhancement Corporation (WREC) working in the Region of the Great Bend of the Wabash River.

Problem

In the previous decade, United States public and private sector construction has contributed approximately one million new single-family homes and over 16,093 km of roads per year. As a result, the current extent of impervious surfaces in the contiguous United States exceeds 113,000 km^2, an area approximately the size of the state of Ohio (Elvidge 2004). In Indiana, more than 404,685 ha of farmland were converted to urban uses between 1992-2002, a trend that has continues through the present day (Thompson and Prokopy 2009). Urbanization increases stormwater volume and decreases infiltration capacity due to the impact of added impervious surfaces and reduced vegetation. An imbalance between development and existing infrastructure has left older combined sewer systems which are frequently overloaded with relatively small rain events, resulting in the direct release of untreated wastewater to receiving streams in overflow events. Separated sewers can reduce the water quality problems associated with overflow events, but result in the direct flushing of pollutants accumulated on paved surfaces into receiving streams. As a result, urban streams are among those with the lowest water quality in the country, with concentrations of fecal coliform bacteria commonly exceeding recommended standards for water-contact recreation (USGS 2001). More than 70 % of urban streams sampled as part of the National Water-Quality Assessment Program (NAWQA) exceeded the USEPA desired goal for preventing nuisance plant growth. Deteriorated water quality and sediment, as well as habitat disturbances, contribute to degraded biological communities in urban streams. The greatest effects are seen in areas with the highest human population densities and concurrent watershed development (USGS 2001). Urban impacts to the Wabash River include combined sewer overflows from five cities upstream of Greater Lafayette and 20 CSO overflow points within Greater Lafayette. Industrial and municipal wastewater, brownfields, development pressures, combined sewer overflows, and storm water directly impact the Wabash River in Greater Lafayette. As a result, this reach of the Wabash River has been listed on the impaired waterbodies list since 2002 for nutrients, pH, E. coli, dissolved oxygen, and impaired biotic communities.

The functions and services furnished by Indiana watershed systems provide for the health, resilience and productivity of agricultural systems, human communities and marine and terrestrial natural ecosystems. The predicted increased prevalence of extreme weather events such as floods and droughts due to global climate change will have wide-ranging impacts on the ability of these watershed systems to continue to provide these functions and services at acceptable levels (Weubbles et al. 2010). Local-level adoption of appropriate and sustainable water resource best management practices (BMPs) have been identified as essential tactics for adaptation to climate change (Semadeni-Davies et al. 2008). Stormwater conservation BMPs, such as rain gardens, rain barrels and permeable pavement offer a means to decrease stormwater volumes and reduce the water quality impacts of the predicted increased water quantity that will result from climate change. While these stormwater conservation practices offer real potential to reduce impacts, they generally have low adoption rates compared to equivalent practices in the agricultural sector. Poor adoption and maintenance could be attributed to several reasons, including more numerous landowners with less property, a lower number of cost incentive programs and fewer formal public education programs than found in the agricultural community. However, there have been few efforts to understand this complex condition and, as a result, there is little information regarding the adoption and maintenance of stormwater BMPs by urban and suburban landowners. This lack of knowledge regarding stakeholder motivations contributes to a high level of uncertainty and may lead to reluctance amongst organizations that might cost-share stormwater conservation.

Research Objectives

The Region of the Great Bend of the Wabash River Watershed is a Mississippi River Watershed with agricultural, forest, grassland, residential, commercial, industrial, and recreational land-uses. The West Lafayette-Lafayette communities spanning the banks of the Wabash River have a combined population of over 150,000 people. Like many similar sized communities across the country, the region is struggling to deal with increasing stormwater impacts to water quality. In September 2008, WREC and Purdue University partners, contracted with the Indiana Department of Environmental Management (IDEM) to initiate the development of a watershed management plan for the Greater Lafayette Region. In May 2011, the second phase of the project began focusing on development of a cost-share program. Following the completion and approval of the watershed management plan in May 2011, the Environmental Protection Agency, TippMont, and the Ford Foundation have awarded several grants to WREC to support this cost-share program in order to promote the adoption of BMPs throughout the Region of the Great Bend of the Wabash River Watershed. The cost-share programs, which began in January 2012, funded households, businesses and municipalities in the installation of practices including rain barrels, rain gardens, bioswales, pervious pavement, green roofs, critical area tree planting, native plantings and urban infrastructure retrofits. Understanding how WREC can increase adoption and encourage the maintenance and diffusion of these BMPs is a key objective of this project. Specifically this project features the following three objectives:

1. To determine what motivates urban and suburban landowners to adopt and maintain stormwater conservation BMPs;
2. To identify how stormwater conservation BMPs spread or diffuse throughout a community;
3. To determine specific watershed management planning recommendations for setting adoption goals and reaching potential adopters for the WREC in the Region of the Great Bend of the Wabash Watershed.

Methodology

The survey results presented here comes from the mail and online survey conducted by the Natural Resources and Social Science lab at Purdue University in summer 2014. Questions included in the survey focused on respondents' perceptions about local water quality, their constraints in adoption and maintenance of rain barrels, their awareness of various best management practices, and themselves in terms of background and demographics. The list of addresses was compiled from the entire list of 461 rain barrel adopters in Wabash River Enhancement Corporation (WREC). Of the 461 surveys sent out, 41 were returned as bad addresses, 127 were completed by mail, and 188 were completed via online survey (the alternative option noted in the mail survey). The Dillman (2000) Tailored Design Method was used with to contact those on the list up to five times (advance letter, 1st mailing of paper survey, reminder postcard, 2nd mailing of paper survey, 3rd mailing of a paper survey with a reminder postcard), which achieved a response rate of 70.0% (n=294, excludes the bad addresses, duplicated responses, and invalid responses).

In collaboration with staff at WREC and Save the Dunes, a checklist with criteria for evaluating the level of maintenance of rain barrels was established. A total of 143 rain barrels in the Great Bend of the Wabash River watershed were successfully assessed between May 30 and June 10, 2014.

Results

Survey

- The majorities of respondents (77.9%, n=289) said they installed it and currently use it.
- Among the respondents who installed the rain barrels, when asking about their purpose for getting a rain barrel, a high percentage of them (90.7%, n=237) said they used it to reduce water use for their yard and house, and 65.8% of them (n=222) regarded it as the most important single factor for getting a rain barrel. From their specified other reasons for getting the rain barrel, some of them mentioned that the inexpensive cost was their main consideration, many of them said they used the rain barrel to water their plants or vegetables in their garden.
- Many of them (62.6%, n=230) responded that they bought their rain barrels for $25 from the City of Lafayette, Tippecanoe County.

- In response to the factors making it difficult for them to continue use the rain barrels, 6.2% (n=227) regarded water pressure issues as a factor influencing them a lot, and 5.8% (n= 226) thought equipment malfunction as a factor concerned them much.
- Over half of them (52.0%, n=223) stated they emptied their rain barrel within a week of filing.
- Most of them (95.6%, n=228) said they used water from the rain barrel to irrigate a vegetable or flower garden.
- For the question about how they learn about rain barrels, 34.5% of them (n=229) said they learnt from City water bill. Among the other specified learning sources (36.2%, n=229), many of them said they heard from their friends, relatives, neighbors; four of them mentioned Master Gardeners; two of them mentioned they learnt it from employee in Food Finders Food Bank; two of them mentioned River Feast of 2013.
- A high percentage of respondents said they never heard of downspout disconnection (51.5%, n=227), grass swales (48.3%, n=230), and French drains (39.5%, n=228)

Assessment

In the Great Bend of the Wabash River watershed, 143 rain barrels were successfully assessed and indexed. More than half of the rain barrels were categorized as excellent.

Category Name	Category Index Points	Great Bend of the Wabash River
Excellent	3	96 67.13%
Acceptable	2	7 4.90%
Unacceptable	1	5 3.50%
Absent	0	35 24.48%
Mean		2.15
Median		3
Mode		3

Additionally, in the Great Bend of the Wabash River watershed, where some homeowners displayed informational signage about rain barrels in their yard, the effect of this signage was analyzed. The scoring distribution is as follows:

Category Name	Category Index Points	No sign present	Sign present
Excellent	3	24 41.38%	72 84.71%
Acceptable	2	1 1.72%	6 7.06%
Unacceptable	1	2	3

		3.45%	3.53%
Absent	0	31 53.45%	4 4.71%
Mean		1.31	2.72
Median		1	3
Mode		1	3

Major Conclusions and Significance

From the social indicator survey results, 95.6% (n=228) said they used water from the rain barrel to irrigate a vegetable or flower garden, 90.7% (n=237) said they used it to reduce water use for their yard and house. This implies that the gardeners or homeowners who take care of their plants will be the potential rain barrel adopters. The cost-share programs in WREC could focus more on targeting these categories of homeowners in their future outreach activity. Water pressure issues (6.2%, n=227) and equipment malfunction (5.8%, n=226) are two major concerns for homeowners to maintain their rain barrels. This implies that future install and maintenance instructions should cover more detailed information on these parts.

In addition, homeowners who did not have informational signage about their rain barrel in their yards had a significantly lower assessment score than homeowners who displayed the signage. This phenomenon is likely similar to "commitment," where those who performed a small initial action were much more likely to agree to a subsequent larger action; these findings have been replicated numerous times (Mackenzie-Mohr and Smith 1999, 46-60). In order to promoting the consistent maintenance of rain barrels in local area, a signage with information "Eco-Champion" and "Protecting the Wabash River" has positive impact on pressuring them to

Publications

Forthcoming – not yet submitted

Grant Submissions

USGS 104G grant – received; PI Dr. Laura Bowling; Can there ever be enough? Analysis of the adoption, penetration and effectiveness of urban stormwater best management practices

Students

2 undergraduate students: Allison Turner, Cheyenne Hoffa

1 graduate student: Yuling Gao

References

Dillman, D. A. (2000). Mail and internet surveys: The tailored design method (Vol. 2). New York: Wiley.

Elvidge, D. (2004). U.S. Constructed Area Approaches the Size of Ohio, *EOS, Transactions, 85*(24)

Mackenzie-Mohr, D. and W. Smith. (1999). *Fostering sustainable behavior: An introduction to community-based social marketing*. New Society Publishers: Gabriola Island, British Columbia, Canada.

Semadeni-Davies, A., Hernebring, C., Svensson, G., & Gustafsson, L. G. (2008). The impacts of climate change and urbanisation on drainage in Helsingborg, Sweden. *J. of hydrology*, *350*(1), 114-125.

Thompson, A. & L.S. Prokopy (2009). Tracking Urban Sprawl. *Land Use Policy, 26*(2), 195-202.

U.S. Geological Survey (2001). Selected findings and current perspectives on urban and agricultural water quality. *U.S. Geological Survey Fact Sheet FS-047-01*

Wuebbles, D. J., K. Hayhoe & J. Parzen (2010). Introduction: Assessing the effects of climate change on Chicago and the Great Lakes. *Journal of Great Lakes Research, 36*, 1-6

Can there ever be enough? Analysis of the adoption, penetration and effectiveness of urban stormwater best management practices

Basic Information

Title:	Can there ever be enough? Analysis of the adoption, penetration and effectiveness of urban stormwater best management practices
Project Number:	2014IN377G
USGS Grant Number:	
Start Date:	9/1/2014
End Date:	8/31/2017
Funding Source:	104G
Congressional District:	IN-4
Research Category:	Water Quality
Focus Category:	Water Quality, Management and Planning, Non Point Pollution
Descriptors:	None
Principal Investigators:	Laura C. Bowling, Linda Prokopy

Publications

There are no publications.

General Report Format

Report Format

Project Id: 2014IN377G

Title: Can there ever be enough? Analysis of the adoption, penetration and effectiveness of urban stormwater best management practices

Project Type: Research

Start Date: 9/01/2014 **End Date:** 2/28/2015

Congressional District: Indiana 4

Focus Categories: Water Quality, Management and Planning, Non Point Pollution

Keywords: urban stormwater BMPs, social indicators, water quality

Principal Investigators: Bowling, L.C. and L.S. Prokopy

Abstract / Summary Stormwater management, including the infrastructure for water conveyance, drainage and treatment, is an increasing water problem for communities of all sizes. This project is addressing the need to improve and enhance the nation's water supply through evaluation of what limits adoption of urban stormwater conservation practices. Urban streams are among those with the lowest water quality in the country. Improvements to stormwater conveyance and treatment infrastructure alone cannot resolve the problem. Stormwater conservation practices, such as rain gardens, rain barrels and permeable pavement offer the potential of decreasing stormwater volumes and reducing water quality impacts, but their utilization is generally lower than their agricultural counterparts. The goal of this proposed work is to improve water quality planning and implementation through recommendations to improve the overall adoption, penetration and permanence of urban stormwater BMPs. This will be achieved by: 1) Evaluating the level of adoption and intensity and duration of sampling needed to demonstrate statistically significant water quality change; 2) Assessing factors influencing practice adoption, penetration and permanence; and 3) Developing watershed management planning strategies for achieving urban water quality goals. Our research approach blendsstatistical analysis with social science techniques to determine 1) how many BMPs do we need? and 2) how can we get them in the watershed?

Problem: While agricultural systems have utilized Best Management Practices to reduce pollution for a number of years, work on urban stormwater management is lacking. The West Lafayette-Lafayette communities spanning the banks of the Wabash River in north central Indiana have a combined population of over 215,000 people. Like many similar sized communities across the country, the region is struggling to deal with increasing stormwater impacts on water quality. Improvements to stormwater conveyance and treatment infrastructure alone cannot resolve the problem. Stormwater conservation practices, such as rain gardens, rain barrels and permeable pavement offer the potential of decreasing stormwater volumes and reducing water quality impacts, but their utilization is generally lower than their agricultural counterparts. Poor penetration is attributed to several reasons, including more numerous landowners with less property, a limited number of cost incentive programs and fewer formal public education programs than found in the agricultural community. Secondly, there is little demonstrated ability to show watershed-scale water quality improvement due to BMP implementation in urban environments, which is a function of both the needed intensity of BMP implementation to enact a desired change, as well as the statistical design of a monitoring program that can detect the expected rates of change.

Research Objectives: This project will address the knowledge gap regarding the watershed-scale effectiveness of urban stormwater BMPS, starting with how many BMPs it takes to show statistically significant water quality improvement and extending to the willingness of landowners to adopt. Our specific project objectives include:

1. Evaluate the level of adoption and intensity and duration of sampling needed to demonstrate statistically significant change;
2. Assess the factors influencing practice adoption, penetration and permanence; and
3. Develop watershed management planning strategies for achieving urban water quality goals.

Methodology: Our approach blends statistical analysis and physical modeling to determine the location and level of adoption and monitoring needed to reach water quality targets, with social science techniques to assess the level of BMP adoption in our urban watersheds, and the penetration and permanence of that adoption, to formulate overall recommendations. This overall methodology is described briefly here.

Objective 1 - Evaluation of the level of adoption and sampling intensity needed to demonstrate statistically significant change includes two primary tasks. Progress has been made on each of these tasks during the initial 6 months of the project.

Analysis of the effectiveness of monitoring experimental design will essentially use power analysis of the extensive Elliot Ditch and Little Pine Creek water quality datasets to quantify how the fundamental choice of experimental design (pre-/post- implementation analysis for a fixed site versus paired watershed) impacts the length of the monitoring program, the feasibility of detecting change and the overall sample analysis cost.

Quantifying the required level and location of adoption of BMPs to achieve the best case water quality target identified through the statistical analysis will be accomplished using the Long-Term Hydrologic Impact Assessment-Low Impact Development (LTHIA-LID) model (Ahiablame et al. 2012). Our LTHIA model implementation will include data from the hundreds of BMPs already installed in the Elliot Ditch watershed. We will calculate both the load reduction anticipated due to all BMPs installed by year 3 of the project, as well as the total number or area of additional urban BMPs required in the Elliot Ditch watershed to achieve the detectability target.

Objective 2 – The factors influencing practice adoption, penetration and permanence will be assessed with respect to three components. Progress has been made in each of these areas during the reporting period.

Assessment of motivations to adopt urban BMPS will be completed through in-person surveys of people who have already adopted BMPs in the Elliot Ditch watershed, people who adopt BMPs in the first five quarters of this grant, and people who received technical assistance from the Wabash River Enhancement Corporation but did not follow through with adoption of a BMP. Surveys for adopters and non-adopters will be developed based on existing social indicators. Developed by PI Prokopy and colleagues (Prokopy et al. 2009, Genskow and Prokopy 2008, Genskow and Prokopy 2011).

Understanding permanence of Urban BMPs requires an assessment of both the property owner/manager and the actual practice are needed. For the assessment of the property owner, we will resurvey everyone who adopted a BMP at least 18 months after the preliminary survey. At the same time as in-person surveys are conducted, Implemented projects will be photomonitored to document project installation, penetration and permanence.

Quantifying penetration will involve a spatial analysis of the mapped practices using spatial autocorrelation statistics to evaluate if there is clustering of individual types of BMPs with respect to different types of neighborhoods, the influence of peer-communication, and the influence of local businesses that have installed BMPs. The second task we will perform to explore penetration focuses on measuring shifts in social norms in the community through social indicator surveys throughout the Greater Lafayette community, BMP technical assistance calls and a content analysis of local newspaper and television articles/news stories to see if there is increased coverage of urban BMPs.

Objective 3 - After increasing our fundamental understanding of what is involved in motivating people, we will distill this information to provide strategies for watershed management planning. There was no progress on these tasks during the reporting period.

Results

Objective 1:

Task 1: Analysis of the effectiveness of monitoring experimental design

Task 1 has focused on methods for data pre-processing to address the seasonality, autocorrelation and skewness in the raw water quality data. The t-test and ANCOVA power analysis assume that the data are independent, and identically distributed, with a normal distribution, and these assumptions are not met by any of the water quality datasets. First, a log transform was applied to the data, to correct for normality in the data as well as heteroscedasticity. Because the data is a weekly time series, there is strong autocorrelation across measurements for some contaminants. To correct for this and remove the seasonality from the data, a sinusoidal term (fourier series) was subtracted from the data. Any remaining autocorrelation was removed using pre-whitening. This modified dataset will be used in both a single site and paired-catchment power analysis to quantify the detectable water quality difference as a function of sample size.

Task 2: Quantifying the required level and location of adoption

Activities have focused on developing the spatial inputs for the LTHIA-LID model. A geodatabase has been created and shared in the Purdue University Research Repository (PURR) project so that all of the project members can access the data.

Creating a SSURGO Soil Database for the study area: Created a personal geodatabase and then imported the shapefiles as feature classes in the geodatabase. The SSURGO text tables were imported to an Access database and then linked soil polygons to soil properties.

Preparing the land use data: There were 15 different categories in the land cover grid map. It was reclassified to 7 major classes for this project (Table 1), Figure 1.

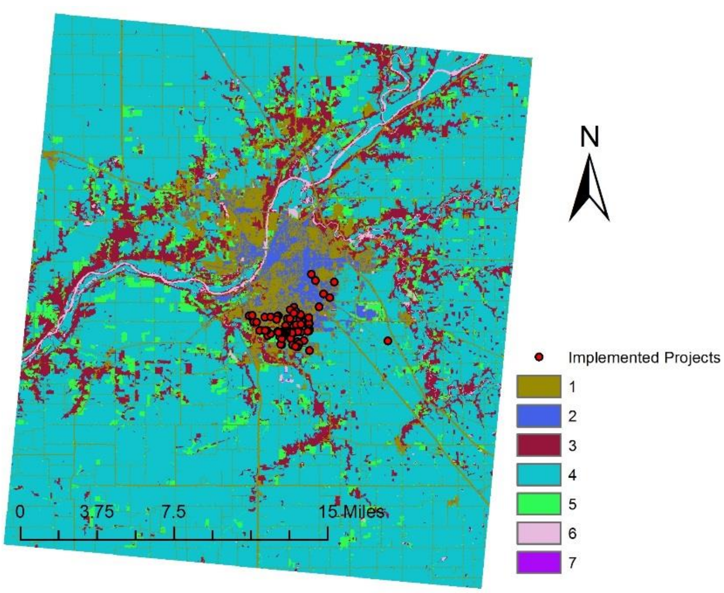

Figure 1 Implemented projects and land cover map of the study area after reclassification

Merging of Soil and Land use data: The soil and land cover data were merged together using the union tool in ArcMap. The sliver polygons (features that have attributes from one feature class because the other feature did not exist in the study area) were deleted from the attribute table.

Table 1: Revised classification of the original NLCD land cover of the study area.

Original NLCD Classification		Reclassification	
Number	*Description*	*Number*	*Description*
1	Developed, Open Space	1	Low Density Residential (LDR)
22	Developed, Low Intensity		
23	Developed, Medium Intensity	2	High Density Residential (HDR)
24	Developed, High Intensity		
31	Barren Land	7	Commercial Area
41	Deciduous Forest	3	Forest/Woods
42	Evergreen Forest		
43	Mixed Forest		
52	Shrub/Scrub		
71	Herbaceous	5	Grass/Pasture
81	Hay/Pasture		
82	Cultivated Crops	4	Agricultural
90	Woody Wetlands	6	Water/Wetland
95	Emergent Herbaceous Wetlands		
21	Open Water		

Creation of SCS Curve Number Grid using Land Cover and Soil Data:

A raster dataset of SCS Curve Number was generated for the study area using land cover and soil data. The SCS curve number is used by many hydrologic models to compute excess rainfall and to calculate the runoff. The CN look-up table was created following the SCS TR 55 (1986) report (Figure 2).

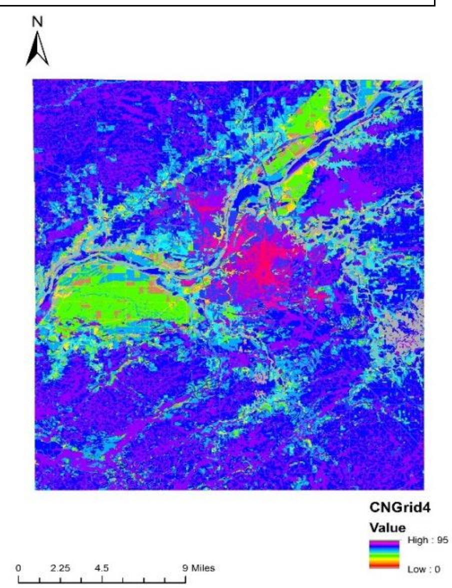

Figure 2: Curve number map of the study area

Objective 2:

Task 1: Assessment of motivations to adopt urban BMPs

In late 2014, the Natural Resources and Social Science Lab in Purdue University conducted two social indicator surveys in Great Bend of the Wabash Watershed, targeting for urban residents and rain barrel adoptees, respectively. These initial surveys of adopters/non-adopters in the region will be followed up with in-person surveys of adopters within the Elliot Ditch watershed. The Urban Residents Survey was mailed out to 1100 urban residents of Tippecanoe County, of which 87 were returned as bad addresses and 278 were completed by mail (response rate 27.4%). The Rain Barrel adoptees Survey was mailed out to 461 rain barrel adoptees known to WREC, of which 41 were returned as bad addresses, 294 were completed by mail or online (response rate 70.0%). The comparison between the two different groups of respondents focused on the same questions asked in both surveys, including their demographic profile, their opinion about water quality issues, their attitudes towards various conservation practices.

The profile of urban resident and rain barrel adoptee is shown in Table 2. There are no significant difference between urban residents and rain barrel adoptees respondents in terms of respondents' age, education level beyond college, and residential lot size less than one acre. More females responded to the Rain Barrel Adoptees Survey than the Urban Residents Survey. The percentage of respondents with high school diploma and some formal school in Urban Residents Survey was higher than that in the Rain Barrel Adoptees Survey; the percentage of respondents with college and graduate degree in Rain Barrel Adoptees Survey is higher than that in Urban Residents Survey. A higher percentage of respondents to the Rain Barrel Survey live on residential lots more than one acre and live on their own property than that in Urban Residents Survey.

Rain Barrel Adoptees respondents were more likely to strongly disagree that it is okay to reduce water quality to promote economic development and were more likely to strongly agree that 'it is important to protect water quality even if it costs me more', and that 'I would be willing to pay more to improve water quality'. Urban Residents respondents were more likely to identify algae in the water, and not enough oxygen in the water as water impairment problems in their area. Rain Barrel Adoptees respondents were more likely to say that stormwater runoff from rooftops, parking lots and roads, discharges from sewage treatment plants, improper disposal of lawn waste, oils and chemicals into storm drains, and street salt and sand were problem sources for water quality pollution in their area. Urban Residents respondents were more likely to identity fish kills, and lower property values as the problem consequences of poor water quality.

Table 2: Demographic Comparison

Survey Respondents Profile		Urban Residents	Rain Barrel Adoptees
Gender	Female	38.8%	57.4%
	Male	61.2%	42.6%
Age	Mean	60.4	55.1
	Range	24~96	25~92
Education	Some formal schooling	3.8%	N/A
	High school	17.0%	8.6%
	Some college	16.6%	12.9%
	2-year college degree	7.5%	9.7%
	4-year college degree	21.5%	30.5%
	Graduate degree	33.6%	38.4%
Residential Lot Size (unit: acre)	1/4 or less	67.4%	63.7%
	More than 1/4 but less than 1	28.0%	23.0%
	1 to less than 5	4.6%	10.1%
	5 or more	0.0%	3.2%
Home Property	Own	88.2%	97.9%
	Rent	11.8%	2.1%

Rain barrels were ranked as the most familiar BMP for urban residents (Figure 3): only 5.5 % have never heard of it; 53.6% were somewhat familiar with it; and 32.3% said they knew how to use it but were not using it currently. Grass swales were ranked as the least familiar practice for urban residents (59.8 %, n=219).

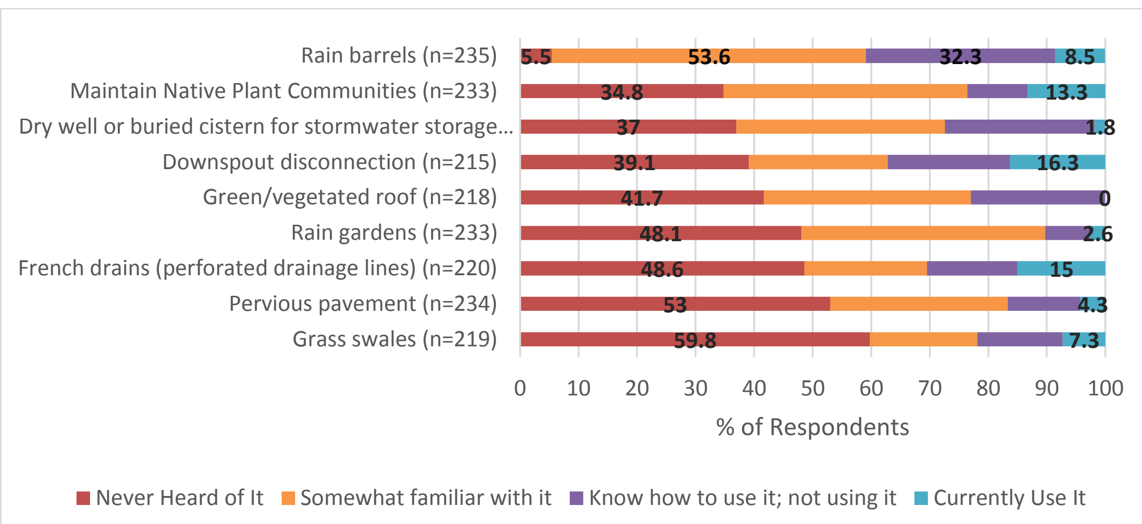

Figure 3: Urban residents' experiences with BMPs

Comparing the rain barrel adoptees' experience with BMPs to the Urban Residents Survey (excluding rain barrels and native plant communities) (Figure 4), green/vegetated roof swere ranked as the most familiar one and downspout disconnection was the least familiar (51.5%, n=227). Figure 5 shows urban residents' usage of water quality improvement practices. The percentage of respondents who installed rain barrels is 8.5% (n=235), ranked as 10th out of 16 practices listed.

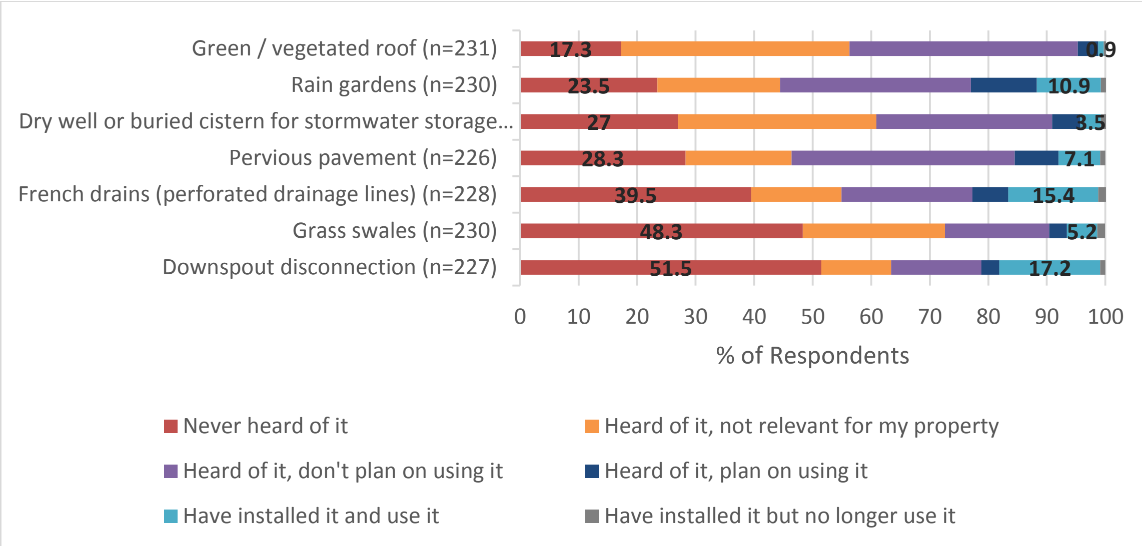

Figure 4: Rain barrel adoptees' experience with BMPs

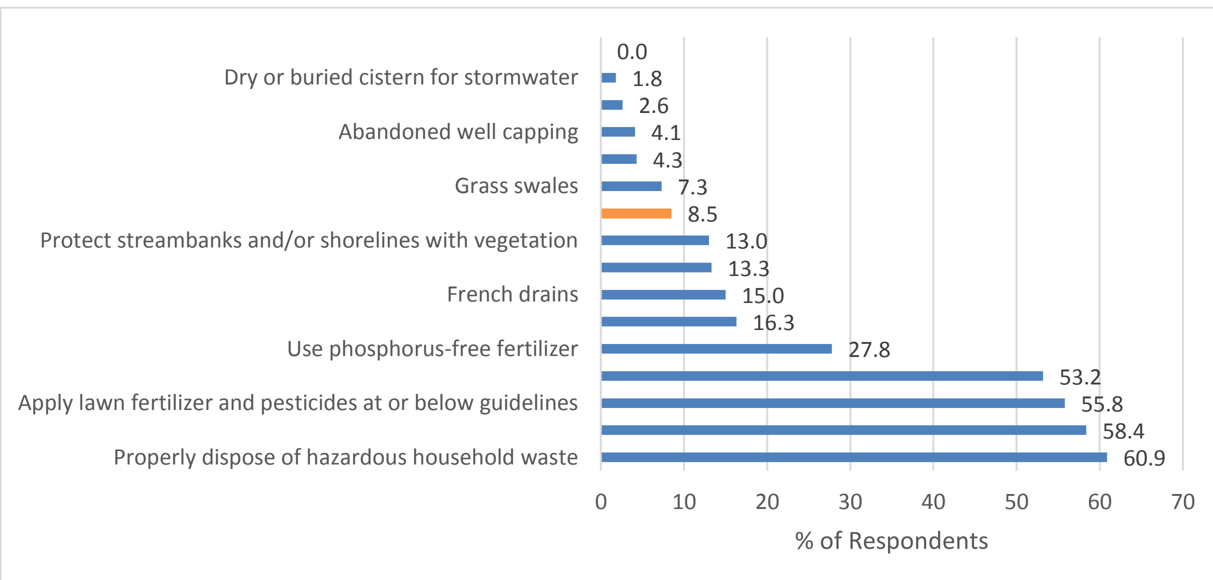

Figure 5: Urban residents' usage of water quality improvement practices

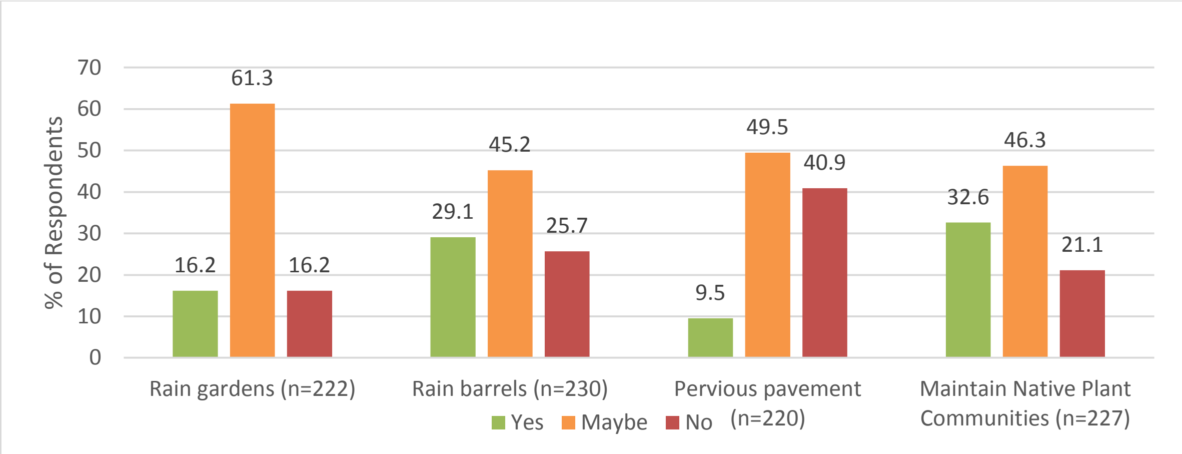

Figure 6: Urban residents' willingness to use BMPs

Figure 6 shows Urban Residents' willingness to use BMPs. 29.1% of respondents said they want to install rain barrels, ranked as the second of the listed four practices. Figure 7 shows the limitations to adopting a rain barrel seen by urban residents. They identified knowledge in how to do it (14.4%, n=222), cost (14.2%, n=225), desire to keep things the way they are (13.8%, n=225), and time required (12.9%, n=224) as the primary limitations.

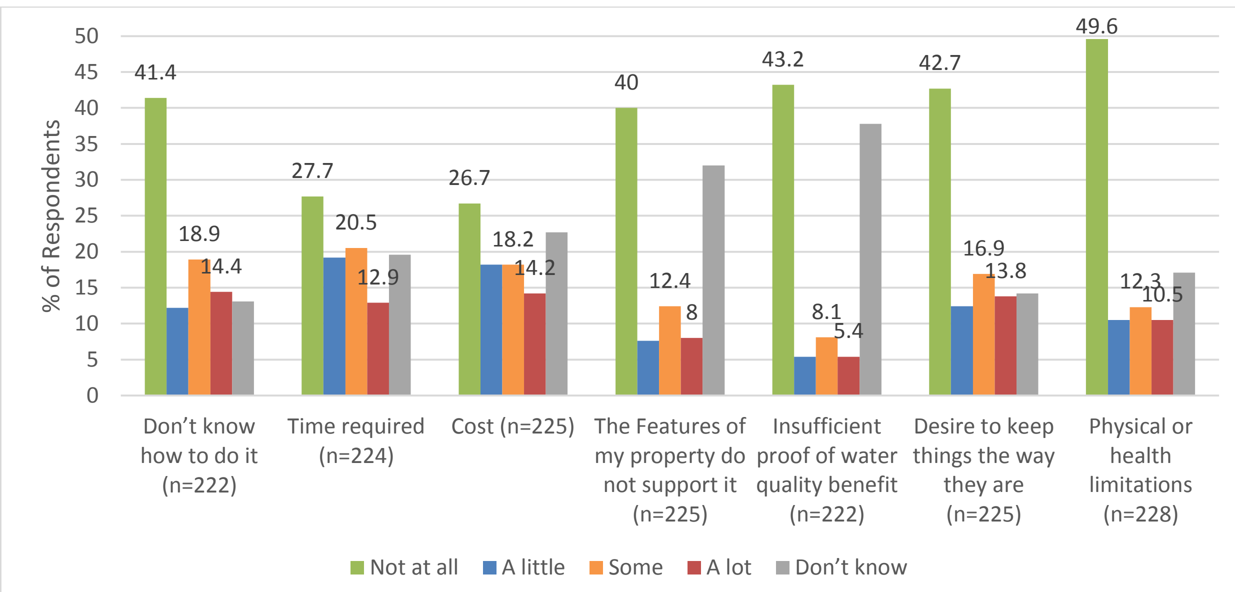

Figure 7: Urban residents' opinion about limitations of rain barrel adoption

Task 2: Understanding Permanence of Urban BMPs:

At the time of this report writing, 202 individuals have been visited, and 44 installed projects have been assessed. Tasks for 2015 include visiting all installed rain barrels and review of the properties who have requested technical assistance in the past to determine if they implemented a practice/project on their own.

Task 3: Quantifying penetration:
Contacts have been made within both West Lafayette and Lafayette, as well as with the Soil and Water Conservation District Office to implement a tracking system for technical assistance phone calls.

Objective 3: *Development of watershed management planning strategies for achieving urban water quality goals:* No progress during this project period.

Major Conclusions and Significance We are 6 months in to a 3 year project and have no conclusions to report at this time.

References

Ahiablame, L., B. Engel, and I. Chaubey, 2012, Representation and evaluation of low impact development practices with L-THIA-LID: An example for site planning. Environment and Pollution, 1(2). Doi:10.5539/ep.v1n2p1.

Engel, B., 2001, L-THIA NPS Long-Term Hydrologic Impact Assessment and Non Point Source Pollutant Model, version 2.1. Purdue University and USEPA.

MD Department of the Environment, 2011, Accounting for stormwater waste load allocations and impervious acres treated, Guidance for National Pollution Discharge Elimination System Stormwater Permits, draft, June 2011.

Publications None

Grant Submissions: None

Students Three PhD level graduate students are working in this project. Yuling Gao (FNR) is working on the stakeholder interviews and assessment of attitudes, beliefs and other factors influencing the decision to implement and maintain best management practices in urban environments. Fushcia Hoover (ABE) is working on the statistical analysis of water quality data and forecasting of the number of BMPs needed to show change. Sanoar Rahman (AGRY) is working on calculation of load reduction due to BMPs using the Long-Term Hydrologic Impact Assessment-Low Impact Development (LTHIA-LID) model.

Information Transfer Program Introduction

None.

Pollution Prevention Strategies for the Public

Basic Information

Title:	Pollution Prevention Strategies for the Public
Project Number:	2014IN373B
Start Date:	3/1/2014
End Date:	2/28/2015
Funding Source:	104B
Congressional District:	04
Research Category:	Water Quality
Focus Category:	Ecology, Education, Groundwater
Descriptors:	None
Principal Investigators:	Fred Whitford, Jagadeesh Anmala

Publications

There are no publications.

A. Titles: Understanding Pesticide Principles and Practical Uses—What Gardeners Should Know About Pesticides

B. Focus Categories: ECL, EDU, GW, NPP, SW, WQL

C. Key Words: Integrated Pest Management, Consumer, Water, Pesticides

D. Project Duration: March 1, 2014 to February 28, 2015. A no-cost extension was granted for February 28, 2016.

E. Funding Requested: $6,000

F. Principal Investigator: Fred Whitford, Ph.D., Director, Purdue Pesticide Programs and Clinical Engagement Professor, Purdue University, 915 West State Street, West Lafayette, IN 47907-2054; Phone: 765-494-1284; Fax: 765-494-1556; Email: fwhitford@purdue.edu

Problem: Studies show that consumers contribute their share of pesticides into streams and rivers flowing near towns and cities. Unlike farmers and commercial application industries, reaching the public on how to reduce or prevent water contamination from pesticide use has proven challenging.

Outreach/Extension Objectives: Many land-grant universities have active Master Gardener programs that reaches a subset of the American population. To qualify as a master gardener in Indiana, the intern attends a series of weekly workshops over a 12-week period to learn about current gardening techniques. One of the required weekly workshops is called *Pesticide Safety and Pesticide Alternatives*. After passing a final examination, they are asked to volunteer 35 hours to their communities. The training, test, and volunteer hours are all part of the initial requirement to becoming a Master Gardener,

Master Gardeners go on to join a county Master Gardener association and community clubs to continue volunteering their time in helping with community projects and educational programs that teach others how to select, grow, and maintain plants in the landscape and garden. In some counties, the master gardeners answer phone calls related to consumer horticulture under the supervision of the County Extension Educator.

In this fashion, the master gardener can provide pesticide safety information directly to members of the public. Their interactions with the public at different levels allows extension information such as whether or not a pesticide is needed, how to read a label, how to use the product safely, and steps they can do in protecting water and wildlife to be delivered to a public largely unreached by traditional programs.

Principal Deliverables:

Extension Publication

The draft publication is being reviewed by the co-authors for technical accuracy and readability. A commercial artist is in the process of creating illustrations for the extension publication. When the author review is completed, the document will be professionally edited and designed.

The current table of contents is as follows:

Work in Progress. Understanding Pesticide Principles and Practical Uses will be made available as a hard copy through Purdue's Media Distribution Center. It will be available by downloading at https://ag.purdue.edu/Extension/PPP/Pages/Publications.aspx. Pesticide safety and Master Gardener coordinators at land-grant universities will be mailed a copy of publication. Indiana Master Gardner instructors will have access to free copies to hand out at training programs or at community events.

Indiana Presentations: A total of 16 presentations were provided to 386 master gardener interns.

<u>2015</u>

- Monroe County Master Gardener Program. Bloomington, Indiana.
- TriCounty Master Gardener Program. Christney, Indiana.
- Floyd County Master Gardener Program. New Albany, Indiana.
- Porter County Master Gardener Program. Valparaiso, Indiana.

2014

- Kosciusko County Master Gardener Program. Warsaw, Indiana.
- Dearborn County Master Gardener Program. Aurora, Indiana.
- Tippecanoe County Master Gardener Program. Lafayette, Indiana.
- Delaware-Madison County Master Gardener Program. Alexandria, Indiana.
- Lawrence County Master Gardener Program. Bedford, Indiana.
- Lake County Master Gardener Program. Crown Point, Indiana.
- Jennings-Jackson Master Gardener Program. Seymour, Indiana.
- Monroe County Master Gardener Program. Bloomington, Indiana.
- Porter County Master Gardener Program. Valparaiso, Indiana.
- Blackford-Jay County Master Gardener Program. Montpelier, Indiana.
- Clay County Master Gardener Program. Brazil, Indiana.
- Miami County Master Gardener Program. Peru, Indiana.

USGS Summer Intern Program

None.

Notable Awards and Achievements